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REPORT No. 4

(Italy, Portugal, Spain and their Colonies)

ON THE QUESTION OF SIGNALLING OF LINES FOR FAST TRAFFIC AND IN MAIN STATIONS. DAYLIGHT SIGNALS. AUTOMATIC BLOCK SYSTEM (SUBJECT XI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1),

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Figs. 1 to 16, pp. 1166 to 1194.

Question XI on the programme of the Madrid Session is in effect a repetition of Question IX which was discussed at the last, the London, Congress in 1925.

Examination of the conclusions then approved emphasises the unanimous agreement reached on important points regarding the basic principles of modern signalling.

However, on one point the Congress did not reach a decision, *viz.* whether two-aspect signals are sufficient or not, or whether those having three or four aspects are preferable. In view of the impossibility of reaching a unanimous opinion on this concrete point, it was decided to remit the question to the programme of the next Congress, in order to have the benefit of the experience gained in each country during the next five years and the results obtained from the ideas and methods practised in each.

Consequently, we have counted on this question of the number of aspects of a signal being one of the important points of discussion in Question XI, and for this reason we propose to examine it specially, although in the countries cited in this report, as will be seen later, only two and three-aspect signalling has been developed, without, however, the experience gained having demonstrated the superiority of one system over the other.

In this report we shall take the sub-

(1) Translated from the French.

ject in the same order as in the question. In Chapter I the types of signal employed will be described, and to enable a better comparison of the methods of signalling of the various countries and railways, we shall classify them according to the functions they perform — distant signals, signals of protection or of entry into stations, and starting signals. The signalling of junctions is dealt with in Chapter II. Daylight signals are studied in Chapter III. Chapter IV deals with the question of automatic block. Chapter V, the last, contains some general views regarding the number of aspects in signalling, and the final recommendations.

CHAPTER I.

Signalling of stations.

SPAIN.

The original signalling of the Spanish railways, with the exception of the Algesiras line which had semaphore signals, was of the normal French type, employing a disc for the distant signal, and a square signal for the stop. But to meet the new demands of traffic and safety, born of the gradual increase in weight and speed of trains, the original signalling has had to be improved, particularly on main lines and principal branches. For this reason there are today quite a number of signalling systems going from the advanced disc signal, as old as the railways and used as the sole means of protection on secondary lines, up to the modern daylight signal, and the automatic block system with three-position signals, which have been working since 1924.

We will describe with sufficient detail and individually the types of signal used on the principal lines, seeing that they relate to solutions of the signalling problem, which could not be mentioned at the London Congress in 1925.

Regarding the fundamental colours used for the signal lights, we must make one general remark. Actually, in compliance with the official signalling regulations in force, the colours used are those of the continental system, *viz.* red for « stop », green for « caution » and white for the « line clear ». These colours are also used in the new signals. But it is admitted that it is desirable to discontinue the use of white for « line clear », and to substitute for it another colour which cannot be confused with the ordinary lighting in towns. In other words, it is desired by this change to have the indication « line clear » always « positive » and thus to prevent the driver, if other white lights are in his proximity, from supposing that the line is clear when « he does not see » the red danger light.

It is for this reason that the Madrid to Saragossa and Alicante Railway Company is considering the adoption of the scheme of colours recommended at the London Congress, and that the North of Spain Railway Company is also anticipating adopting the same scheme later on.

North of Spain Railway Company.

Distant signals.

Stations and other dangerous points are always protected by a distant signal.

The following types of distant signal are employed.

a) *Red disc.* — Which enables the following indications :

— *Advance cautiously and stop at home signal* (or at the point protected if

there is not a home signal) : red disc perpendicular to the road, red light at night.

— *Home signal clear, or point protected free* : disc parallel to the road, white light at night.

b) *Two-aspect daylight signal.* — On the electrification of the Pajares line, between Ujo and Busdongo, a line subject to very unfavourable atmospheric conditions, daylight signals were adopted in 1924. Distant signals were put in, which give identical indications to those given by the discs at night, with the only difference that for « line clear » light yellow has been adopted instead of white.

c) *Three-aspect daylight signals.* — This type of signal was introduced on the North of Spain when the first automatic block installation was put in. This signal is described in the chapter relating to daylight signals.

Home signals.

In stations where the old type of signalling is retained, there is no fixed home signal. The rule prescribes in this case a stop before the point protected if the distant signal is at danger.

The home signals in use are the following :

a) *Square stop signal.* — The face of the screen is divided into four squares, two white and two red. At night the *danger* indication is given by two red lights, and that of *line clear* by one white light only.

b) *Two aspect daylight signal.* — This type of signal was introduced by this Company at the same time as the two-aspect « distant » daylight signal. It is exactly similar to the square signal described above, and gives the two indications at night in the same manner, except that yellow lights are used instead of white.

When there are facing points, the stop signal is followed by a route indication provided there are sufficient semaphore arms as routes capable of being followed by the train. These arms are placed one above the other, and correspond from top to bottom to the different routes possible from left to right. The arms fall to « clear ». At night, arms which are horizontal show a violet light, those which are inclined a white light.

There is another type of route indicator for daylight signals which is described in Chapter III.

c) *Three-aspect daylight signals.* — This type of signal was introduced by this Company at the same time as the « distant » three-aspect daylight signal, *viz.* when automatic block was installed. It will be described in the section to which it belongs in this report.

Starting signals.

In stations with little traffic there is no starting signal, but in those where movements are frequent, and where there is interlocking, it is usual to have one or several starting signals, of the same type and shape as those previously described for the home signal (square stop signal) placed on the different departure roads.

Starting signals are not preceded by an advanced starter. It is only in the case of the automatic block system that starting signals which are also block signals are repeated at a distance by the home signal into the station.

Madrid to Saragossa & Alicante Railways.

Distant signals.

The use of a distant signal is obligatory to protect a station or any other dangerous point. The distance at which this signal is placed varies according to its visibility, the profile of the line, or the braking distance. The most frequent distances vary between 500 and 1 000 m. (1 640 and 3 280 feet).

The types of distant signal in use are :

a) *Red disc.* — This signal of the well known standard type consists of a red disc with a white border, and gives the following indications :

— *Proceed cautiously and stop at the home signal* (or in front of the protected spot if there is no home signal) : Originally red disc perpendicular to the road; red light at night. When the projected new colour scheme is adopted, this disc and the light for this indication will be yellow.

— *Home signal at « clear » or protected spot free.* — Disc parallel to the road; *i. e.* effaced. White light at night. According to the new colour scheme, the white light will be replaced by a green light.

b) *Three position semaphore.* — This type of signal was introduced on the Madrid to Saragossa and Alicante Railways when automatic block was installed on certain lines. Strictly speaking the three-position signal is neither a distant nor a stop signal. As is well known, it has arisen from the fusion of these two signals by a perfectly logical process of simplification. When the block sections into which a line is divided are short, each block signal and the following distant signal are very near together. That is why in this instance the same post or bracket has been used for the two signals (English or Italian systems for instance). Now, the four possible combinations of track indications by the two signals are reduced to three useful indications : « *stop* », « *signal ahead at danger* », « *signal ahead clear* » which can be given by a single three-position signal.

This has great advantages not only because of its simplicity and economy, but also because of its clearness and convenience, since there is only one signal to be observed instead of two.

The « *distant* » indications which can be given by a three-position signal are two, *viz* :

— *Get ready to stop at home signal :* arm inclined upwards to 45°. At night a green light, which will be replaced by yellow when the new colour scheme comes into force.

— *Continue at normal speed up to the next signal :* arm vertical. White light at night which will be replaced by a green light under the new colour scheme.

Attention may be drawn here to the interesting differences between the use of a three-position signal as a « distant » signal and that of the disc or ordinary two-position distant signal. Actually, the indication « get ready to stop at the home signal » is *neither identical with nor equivalent to* that given by the red distant disc « at danger » on nearly all the railways which use it. This not only requires one to get ready to stop at the home signal, but also to reduce speed at once (proceed cautiously) for it protects shunting movements at the home points, or a train stopped at these points.

This dual function of the red disc at danger has certain disadvantages by im-

parting to drivers a tendency to assume that the indication relates to the least restrictive case (stop at the « home ») which is the most frequent. This tendency may be the cause of accidents, if the disc is protecting a shunting movement or a train held in front of the points, should the conditions of visibility or braking be defective. These eventualities are avoided with the three-position signal employed as stated, because to each position there is a definite order. If the section between the distant signal and the « home » *is not clear* this signal (arm horizontal — red light) requires an immediate stop, and then proceed *cautiously*. If it simply requires a stop at the home signal, the corresponding position (arm inclined upward at 45° — green light) gives the indication definitely, which avoids premature application of the brake, and loss of time by unnecessary reduction of speed.

c) *Three-position semaphore, with « calling on » arm.* — With the increase in the speed and weight of trains has arisen the need of informing the driver by means of the distant signal if the entry into the station should be on the through road or by a loop line.

As the three positions of the semaphores employed represent three characteristic and well defined indications for block working, it has not been thought wise to complicate them by indicating, for instance, with the arm inclined to 45° that the speed should be reduced for running on to a loop line. The use for this purpose of three positions in the distant signal is established on some railways (Portugal, Holland, Belgium) but when the three-position semaphore is employed for block indications, the 45°-position indicates that the signal ahead is at danger, and consequently requires the driver to « be ready to stop at the next signal ». It is not advisable to give to this position a new signification such as « pass the signal ahead at reduced speed » since, because this signification is less restrictive, such double use might become dangerous.

To avoid this, the indication « loop line » is given by a calling on arm placed below the main arm. Thus the main arm continues to apply exclusively to the direct road, and when access thereto is not authorised (main signal arm inclined at 45°) it is the calling on arm which indicates if entry is authorised or not to the loop line.

The indications which can be given by the compound signal are shown in figure 1.

Home signals.

In stations which still retain the old type of signalling, except for the « distant » disc, there is no fixed home signal. The rules for this case prescribe that trains which find the distant signal at danger (red disc passable at slow speed) must stop in front of the first points, and there await orders from an authorised station official.

Indication of through road, or loop line (usual for single lines) is given simply by means of point indicators which work in connection with their operating lever.

The home signals in use are the following :

a) *Square « stop » signal.* — Red board with a white border. At night, « danger » is indicated by two red lights, and « line clear » by two white lights. When the new colour scheme is adopted, the white lights will be replaced by green ones.

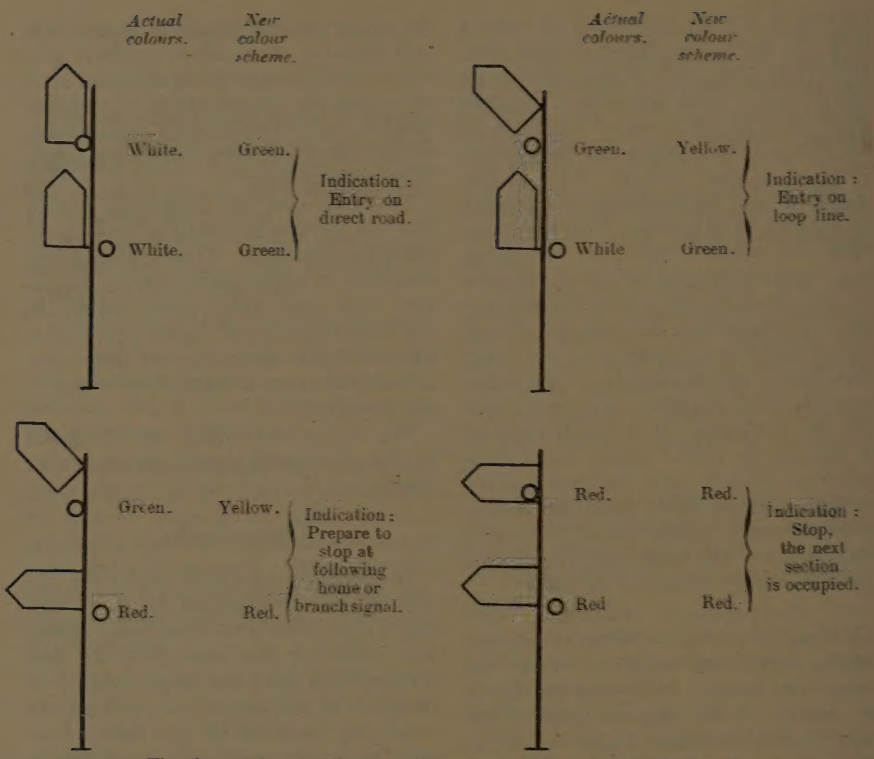


Fig. 1. — Three-position semaphore signal: calling-on arm for loop line (Spain, Madrid-Saragossa-Alicante).

In stations where this signal is used, direct road or loop line is seen by means of the point indicators referred to in the preceding paragraph.

b) *Three-position semaphore for block working.* — On the lines where automatic block is installed, the home signal is also a block signal. Under the heading « Automatic block » this method of signalling will be described in detail, for which reason, in describing the types of home signals at stations, we simply mention the use of the three-position semaphore as a home signal. As regards running on the through road, it is sufficient to say these signals act also as distant signals for the starting signals, as normal block conditions exist between the starting and home signals. Consequently the home arm raised to 45°, or a green light, indicates that the starting signal is at danger, whilst the arm vertical or a white light gives « line clear ».

If there are *facing* points the home

signal has several arms. One arm is for the through road, a second for all deviations to the right, and a third for deviations to the left. These arms are arranged on *three-post brackets*, the arm for the through road being placed higher than the others. Though unaware of the geographical lay-out of the roads, the drivers know, thanks to this arrangement, whether the line they are entering is the through road, or not. In this case only the arm for the through road is connected to the starting signal.

To sum up, these home signals, besides governing the entry to the station, indicate also whether a through run is authorised or not, and also if entry is permitted to the through road, or a loop line. In the latter case they indicate also whether the direction is to right or left.

Starting signals.

In stations which retain the old type of signalling, there is no starting signal. Indication that the road is clear is given manually by the station official on the platform.

In the other stations the starting signals are of the same type and form as the home signals already described (square board, or three-position semaphore for block working).

In through stations, a starting signal is placed only on the through or main road. This signal is interlocked with the points behind it, and with the derailers on the lines directly connected with the main line. In other cases, the various sidings and departure platforms are furnished with starting signals. In the sidings of secondary lines, group signals are sometimes employed for authorising the departure towards the main lines from any road in the siding.

Starting signals apply to the road to which they correspond. They are line signals, and not route signals.

If the departure from the road within the station can be on to various lines and in different directions a route signal is employed in some cases, having as many signal arms as there are routes. By this means the route is indicated whatever may be the departure road.

In the old type of signalling on the Madrid to Saragossa and Alicante, where the square stop signal is used as a starting signal, the position of this signal is not repeated at a distance by another signal. For through trains this is done indirectly by the distant disc signal of the home signal, because the rule prescribes that any through train which has to make an unforeseen stop in the station must be advised by placing the distant signal at danger. We consider this double indication by the disc unsatisfactory. The adoption of automatic block, thanks to the use of the three-position semaphore, has solved in a simple and satisfactory manner the problem of indicating by the home signal the position of the starting signal, as previously explained.

Other Lines.

The Andalusian Railways employ for distant signals only the disc type, except on their Algesiras line, where the « distant » is an arm signal. In certain special cases, besides the distant signals mentioned, square « absolute stop » signals are used.

The system of signalling on the West of Spain Railways is based on the use of discs for the distant signals, similar to those adopted by the other Spanish Railways using this system of signalling.

In illustration of what has been said about signalling on the Spanish Rail-

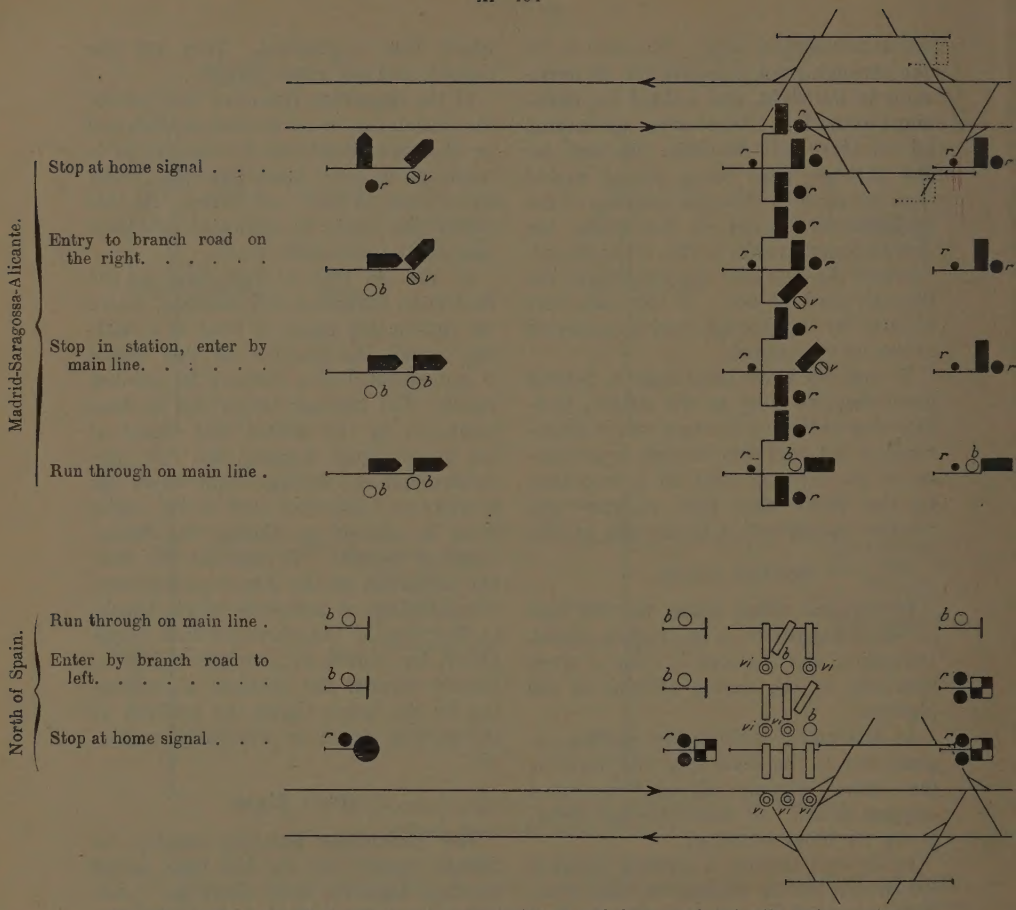

Madrid-Saragossa-Alicante.
Stop at home signal . . .
Entry to branch road on the right. . . . . .
Stop in station, enter by main line. . . . . .
Run through on main line .
North of Spain.
Run through on main line .
Enter by branch road to left. . . . . .
Stop at home signal . . .

Fig. 2. — Examples of signalling at a station with up and down road and with facings points.

ways, figure 2 represents two types of signalling of a station with double track and facing points to loop lines at right and left.

ITALY.

Distant signals.

A distant signal is always employed to protect stations and dangerous points.

The types of distant signals employed are the following :

a) *Red disc.* — This disc is of the standard type and the usual indications are given by it. At night it shows a red or white light.

b) *Distant semaphore.* (belongs to the 2nd category). — It is formed by a red

arm with a white transverse band on which is painted the figure 2 in order to distinguish it from the home semaphore (semaphores of the 1st category). At night this figure shows on the glass of the lantern. The following indications are given by means of this signal :

— *Stop; then advance cautiously* until the end of the train is protected by the signal; arm horizontal and red light at night.

— *Line clear :* arm inclined downwards and green light at night.

When the disc and the distant arm have not the visibility prescribed in the rules, the disc and the arm are preceded by a fixed « reduced speed » signal (green board and at night green light).

c) *Repeating arm.* — This is formed by a fish-tail arm painted yellow with a white vertical band. This signal always precedes the absolute stop semaphores (semaphores of the 1st category). The indications given by this signal are as follows :

Stop at the home signal : arm horizontal, yellow light at night.

Line clear : arm inclined downwards, green light at night.

In some cases the proximity of distant signals is announced by means of five parallel bars between them and inclined at 45° to the road; and on some electrified lines the eight posts which precede the « distant » and « stop » signals are marked with a white helicoïdal line.

Home signals.

On secondary lines there are no other protecting signals than the distant signals already described. On main lines the absolute stop semaphore (1st category) is used for the « home » in the manner indicated previously. This signal is formed by a red arm cut square at the end and with a white transverse band. The indications it gives are as follows :

Stop : Arm horizontal, red light at night.

Line clear : Arm inclined downwards, green light at night.

In important stations with facing points which, in addition to the entry by through road, allow passage on to loops, various solutions are employed. One of them is the use of multiple semaphores, with as many arms as there are directions capable of being followed by the trains. These arms are carried on brackets, or are placed one above the other on a single post. They are identical with those of the absolute stop signal and like these they clear downwards. In other cases a semaphore arm for the branch line is used coupled to the same axis as the home signal. This arm is yellow and its end is cut in the form of a circle. In this case the indications which can be given by the two arms together are :

— *Stop :* The two arms horizontal, red light at night.

— *Entry to loop line :* Home arm inclined downwards and loop arm horizontal, two yellow lights at night.

— *Entry to through road :* Both arms inclined downwards, green light at night.

In important stations the position of the starting signal is indicated at the home signal. For this purpose the distant arm for the starting signal is placed on the same axis as the home signal, a yellow fish-tail arm. The indications

which these two arms together give in this case are :

— *Stop :* The two arms horizontal, red light at night.

— *Advance : starting signal at danger :* Home arm inclined downwards and distant arm for the starting signal horizontal. Yellow light at night.

— *Line clear :* The two arms inclined downwards. Green light at night.

Sometimes the distant signal for the starting signal is mounted on the axis of the home signal which already carries an arm for a loop line. In this case the indications given by the three arms together are four in number and are determined by the positions and the lights indicated.

Starting signals.

In certain stations starting signals are employed of the same type as the home signals. The position of these starting signals is indicated by the home signal in the manner described in the preceding chapter.

PORTUGAL.

Distant signals.

The types of distant signals in use are as follows :

a) *Disc.* — This is a red disc with a white border and gives the following indications :

« *Advance with caution and stop at home signal* » and « *home signal clear or point protected free* » in the usual manner. At night a red light is used for « stop » and a white light for « line clear ».

In stations where trains must reduce speed to enter loop lines, the distant disc is followed by a warning disc which is distinguished from the first by having its front painted green with a white border.

With the screen perpendicular to the road, or a green light at night, the first set of points may be passed at a maximum speed of 10 km. (6.2 miles) per hour but a stop is not required. With the screen effaced or a white light at night, no special precaution is prescribed.

b) *Three-position semaphore.* — This semaphore has its free end like an arrow head and its front face painted green with a white border in V. This three-position signal is used as a distant signal for the home, but is at the same time a distant signal for the starter. It gives the following indications :

— *Stop at the home signal :* Arm horizontal, red light at night.

— *Stop in the station* (Home signal clear and starting signal at danger) : Arm inclined 45° upwards and green light at night.

— *Passing station without stopping* (home and starting signals clear) : Arm vertical upwards and white light at night.

In order to advise the proximity of starting signals, in some cases five boards are used which precede these signals and are located at 50 m. (164 feet) apart. They are painted white and marked in black figures 5, 4, 3, 2 and 1 in the direction of running.

Home signals.

In stations which retain the most simple type of signalling there is no fixed home signal, but in stations of some im-

portance home signals are always employed.

For the home signal the absolute stop arm is used cut square at the end. It is painted red and has a white transverse band. This signal can give the following indications :

— *Stop :* arm horizontal and at night two red lights.

— *Line clear :* arm inclined downwards and two white lights at night.

In important stations with facing points which allow passage to loop lines in addition to the straight run through, stop signals are employed provided with as many arms as there are routes capable of being followed by the train. These arms are identical with those of the stop signal and like them clear downwards. They are mounted on a single post one above the other, and correspond from top to bottom to the possible routes from left to right.

Sometimes on the same post as the home signal a shunting signal is mounted giving entry to sidings and for shunting movements. It is like the home signal but the arm instead of being square at the end terminates in a small circle.

Starting signals.

In stations of some importance starting signals are employed, single or multiple, according to the routes which a train can take on leaving; one for each outgoing road. Their type, working, and signification are identical with those of the home signal arms.

Figure 3 shows a type of signalling in a double track station with facing points to loops at right and left (Italy and Portugal).

CHAPTER II.

Signalling at junctions.

In the three countries to which this report applies signalling at junctions on the open road differs little one from the other. In the direction of running of the trains towards the main road (points trailed), a signal is placed at each loop line and preceded by a distant signal. These two signals are similar to those used for signalling the entry into stations.

For running towards the facing points (see fig. 4) a semaphore provided with as many arms as there are routes is used in Italy and on the Madrid to Saragossa and Alicante Railways. These arms are carried on brackets and that which corresponds to the through road is placed higher than the others. In Portugal the arms are placed one above the other, and correspond from top to bottom to the routes reading from left to right, without distinguishing between through road or loop line.

The North of Spain Railways use as the protecting signal the square chess board, red and white, and the point indicator which we have described for entry into stations; that is to say the turn-out is signalled in the same manner as the entry to a station with facing points.

Under the heading « Daylight signals » we describe a new arrangement for indicating the position of the points adopted by the North of Spain Railways when light signals were installed.

As starting signal the red disc is used on the Portuguese Railways and on those of the North of Spain, and the fish-tail semaphore on the Italian State Railways. The Madrid to Saragossa and to Alicante Railways use also the distant

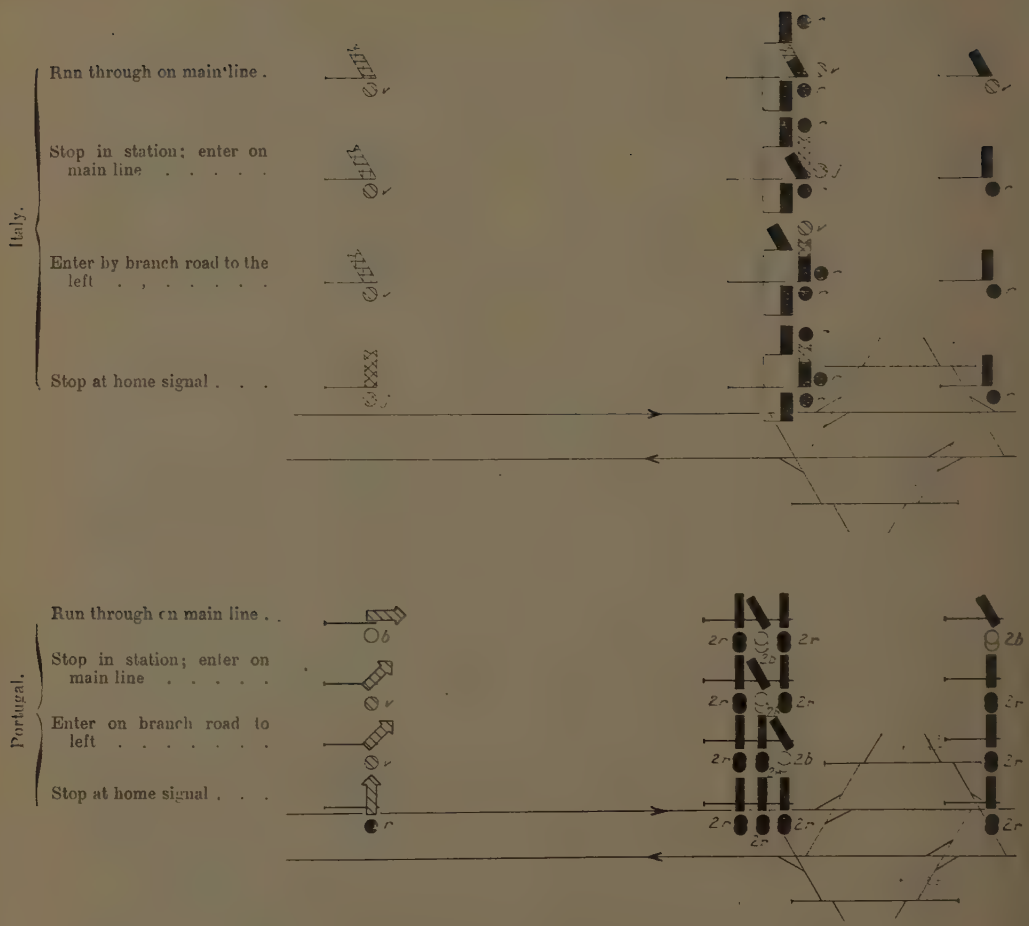

Italy.
Run through on main line .
Stop in station; enter on main line . . . . .
Enter by branch road to the left . . . . . .
Stop at home signal . . .
Portugal.
Run through on main line . .
Stop in station; enter on main line . . . . .
Enter on branch road to left . . . . . .
Stop at home signal . . .

Fig. 3. — Examples of signalling at a station with up and down road with facing points.

disc in the installations which ante-date a certain period, but on the lines where the automatic block is installed three-position signalling has been adopted. The junction signal station is also a section block. Consequently signals which have this double function are controlled by levers interlocked with the points, and by track relays in the case of automatic block.

The Madrid to Saragossa and to Alicante signalling shown is figure 4 represent this case. The signal which precedes the protecting signal is provided

with a calling-on arm which allows it to indicate through road or loop line, as has been described is connection with starting and home signals at stations.

CHAPTER III.

Daylight signals.

To our knowledge, among the railways of the countries to which this report applies, only the North of Spain and the Madrid to Saragossa and to Alicante Railways (Spain) use daylight signals with coloured lights.

The first installation of signals of this kind was put in by the North of Spain in 1924 on its Pajares line, coincident with the electrification of this line. The daylight signals are two-aspect and they are of two kinds, respectively equivalent to the distant discs and the square home signals. They give the same indications as the latter at night, with the sole difference that in the daylight signals yellow replaces white.

In figure 5, the diagrams *a* and *b* represent respectively the distant and the home signal.

Formerly, in 1927, at the installation of automatic block between Madrid and Pozuelo, the North Company adopted three-aspect daylight signals. Notwithstanding the use of three-aspect signals, they adopted three distinct types of signal, represented in figure 5 by *c*, *d* and *e*, which correspond respectively to the open line block signal, the distant signal in advance of the home signal, and the home signal.

Besides the installations mentioned, the North of Spain is putting in daylight signals on the lines from Barcelona to Manresa (64 km. = 39.7 miles) and from Medina to Miranda (253 km. = 157.2 miles). Those comprised between Medina and Venta de Baños (79 km. = 49.1 miles) will be three-aspect and will work as automatic block signals.

On the Madrid-Saragossa-Alicante Lines, in the first block installations the first daylight signals were put in as a trial in place of certain semaphore signals, the visibility of which was not satisfactory because they were against dark backgrounds. The very favourable reports from the Locomotive Running Department and the good results due to their great visibility has now caused them to be adopted as the normal type of signal for future block installations.

The types of daylight signal employed are those shown by *f*, *g*, *h* and *j* in figure 5. As the daylight signals give the same indications at night as three-position semaphore signals, it is considered that the co-existence of these two types of signal is not objectionable.

Figure 6 represents a splitting signal at the entry to a station to indicate through road or turn-out, attained by means of daylight signals.

The Madrid-Saragossa-Alicante Lines have also tried daylight signals (ground or dwarf signals) as shunting signals in several stations situated on the sections fitted with automatic block.

The daylight signals employed by the two companies cited are of a well known type of American manufacture. No use is made of a reflector to obviate phantom indications by reflection of the sun's rays. The light unit is formed by two stepped lenses one behind the other; the inner one coloured and the outer clear. On curves a special lense is employed to suitably disperse the rays.

The lighting of these signals in the case of the North of Spain is by means

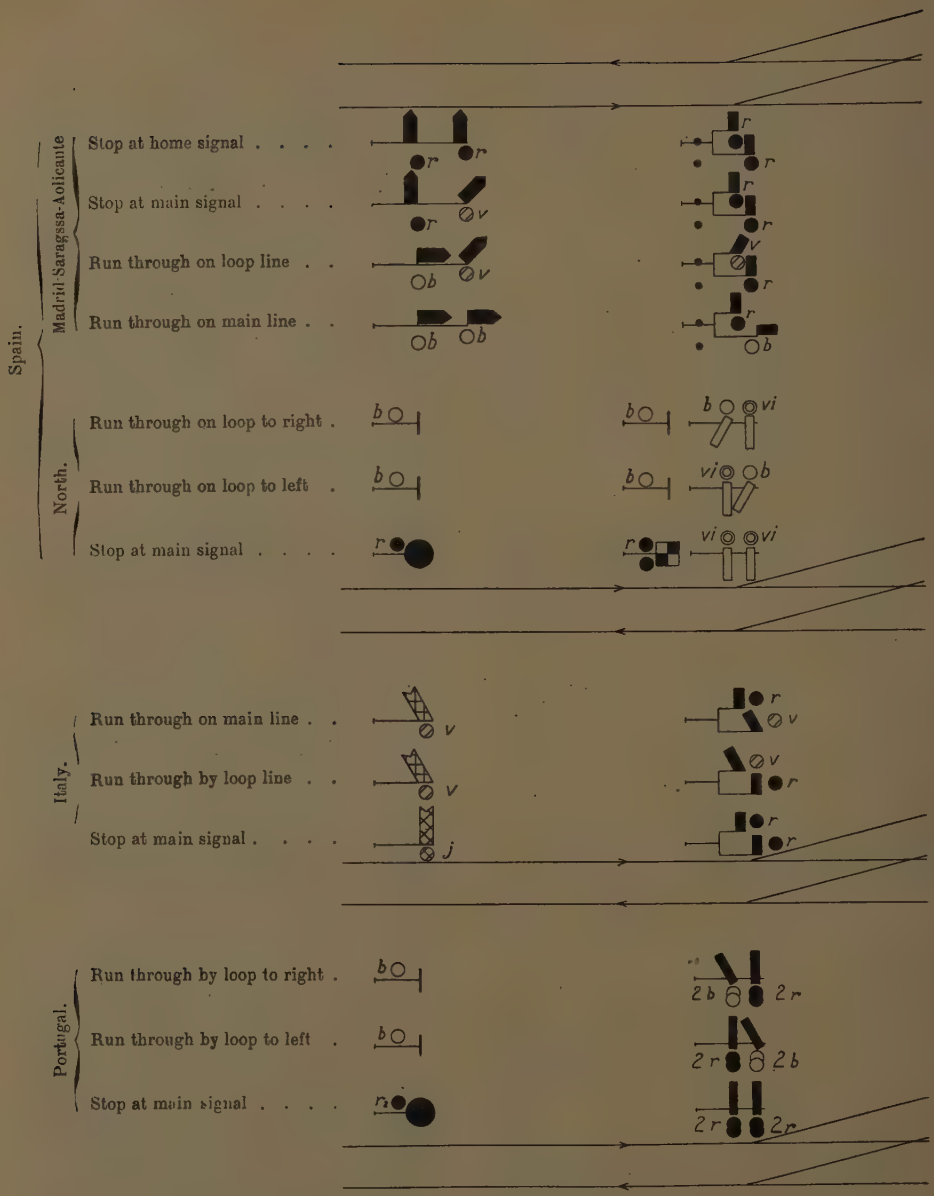
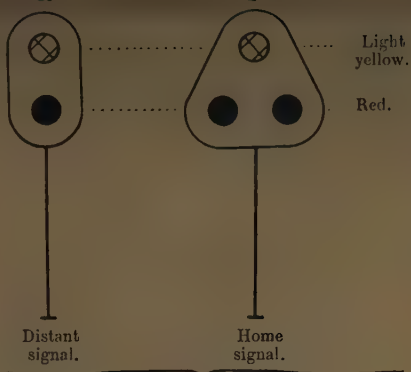
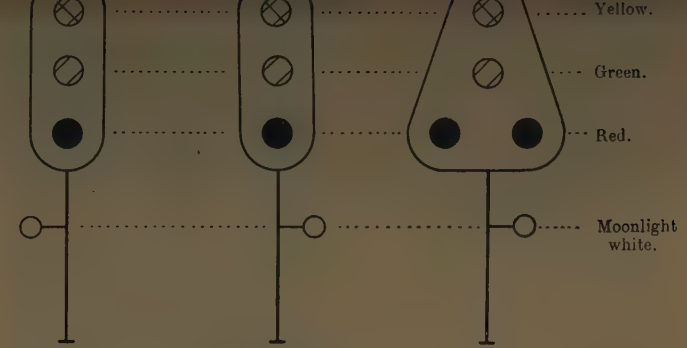

Spain.
Madrid-Saragssa-Aolicante
Stop at home signal . . . . .
Stop at main signal . . . . .
Run through on loop line . .
Run through on main line . .
North.
Run through on loop to right .
Run through on loop to left .
Stop at main signal . . . . .
Italy.
Run through on main line . .
Run through by loop line . .
Stop at main signal . . . . .
Portugal.
Run through by loop to right .
Run through by loop to left .
Stop at main signal . . . . .

Fig. 4. — Signalling of turn-outs when running towards facing points.



Two-aspect signals for protection of a station.



Three-aspect signals-automatic block-system

Daylight signals of the North of Spain Railways.

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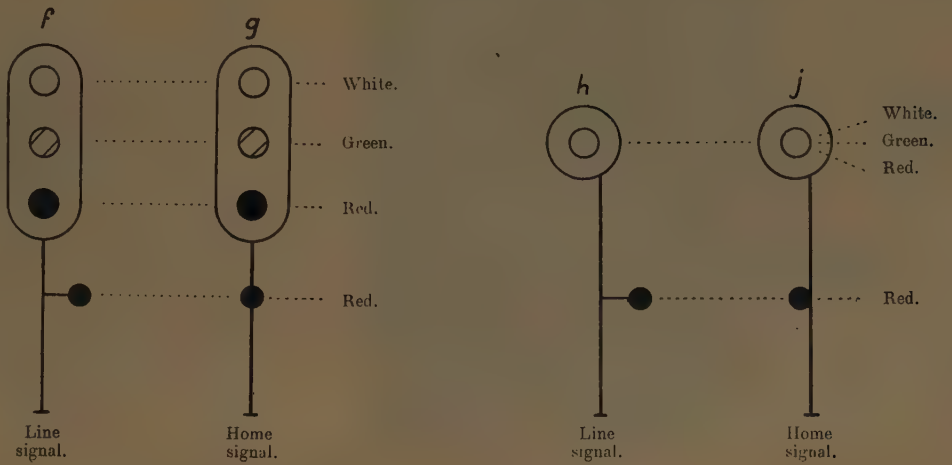


Three-aspect light signals of the Madrid-Saragossa-Alicante Railways.

Fig. 5. — Daylight signals,

Fig. 6. — Home daylight signal, with facing point. (Spain, Madrid-Saragossa-Alicante).

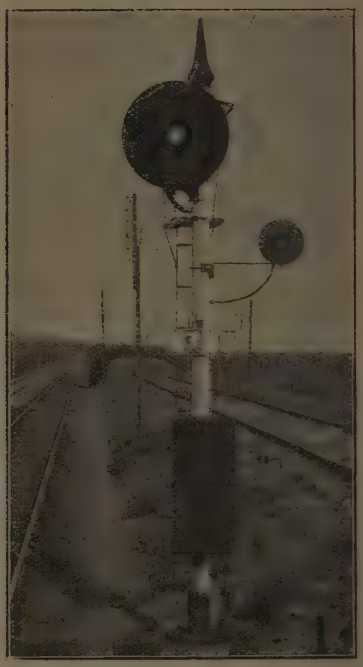


Fig. 7. — Three-indication daylight signal with one lens (Spain, Madrid-Saragossa-Alicante).

of two lamps in parallel, one of them being located within the focus of the lenses. The power of each lamp is sixteen watts.

On the Madrid-Saragossa-Alicante Lines, 12-volt 60-watt lamps are used, with double filament, under-run to assure their life. It has been noticed that the second filament fails usually shortly after the first fuses. The lamps are kept in service for six months only, to prevent their being worn out, and thus the number of lamps which fail is practically nil.

With the Madrid-Saragossa-Alicante Lines, a few daylight signals have been installed, by way of trial, having three-aspects with only one light, constructed by the General Railway Signal Company. Figure 7 shows the outward appearance of this signal and figure 8 is a diagram of its construction and the typical circuits employed when they are used in automatic block signals.

This signal is formed by a two-element three-position relay, the rotor of which moves a vane on which are mounted three coloured lenses which pass between the

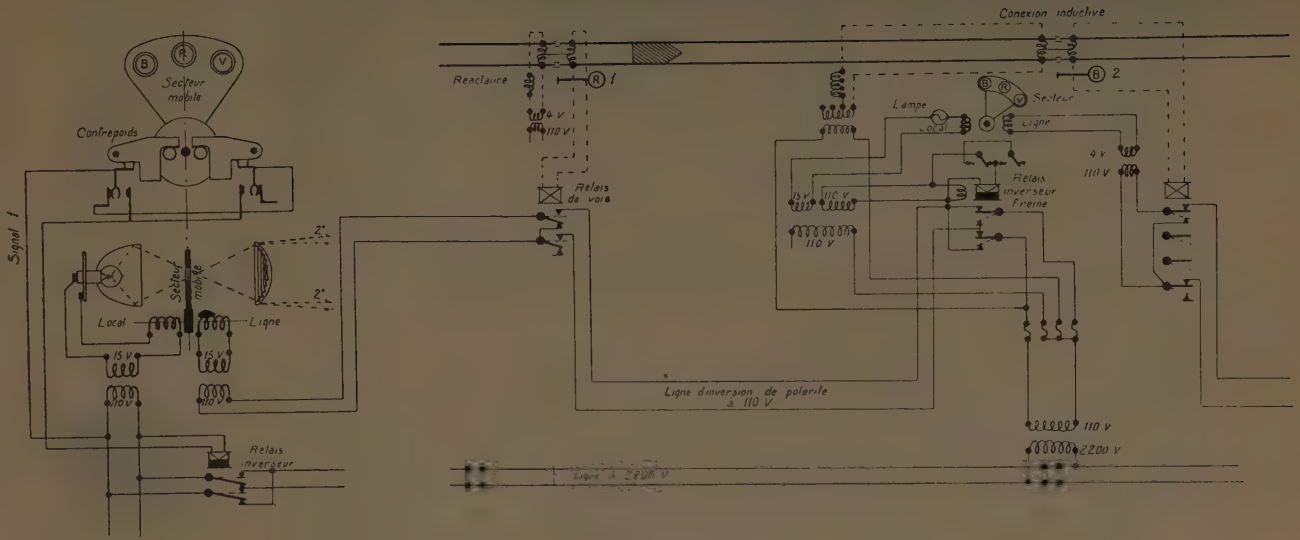


Fig. 8. — Typical circuits of a three-indication daylight signal with one lens (as block signal on the open road).

Explanation of French terms: Connection inductive = Inductive connection. — Contrepoids = Counterweight. — Ligne d'inversion de polarité à 110 volts = 110-volt polarity reversing wire. — Relais de voie = Track relay. — Relais inverseur = Reverser relay. — Secteur mobile = Mobile sector.

focal light and the outer lens. The red colour corresponds to the neutral or de-energised position, a position which is obtained by means of a counterweight, thus avoiding springs which might break and fail. The use of a parabolic reflector in this signal is possible without any disadvantage because phantom indications due to the reflection of the sun's rays are not to be feared, such reflections showing only the colour which corresponds to the position of the mobile sector. This allows a notable reduction in the lighting energy and thus a saving in current. This type of signal offers also advantages of simplification and economy arising from the use of one single light in place of three; and also of much reduced dimensions, a very appreciable advantage in certain cases (in tunnels for instance), where limited spacing has to be provided for.

The results obtained by this type of light signal are completely satisfactory, but it must be remarked that the trial period is not yet sufficiently long to admit of a conclusive value being attributed to it.

CHAPTER IV.

Automatic block.

The automatic block system has been only applied on a scale which is not merely a simple trial but a serious test of automatic working on their principal rapid transit lines by two railway companies in Spain; the North Company and the Madrid-Saragossa-Alicante Company. At the present moment we do not know of any automatic block installations working under the above conditions either in Italy or Portugal. The Portuguese Railway Company proposes to install the automatic block on the line from Caes do Sodre to Cascaes comprising 26 km. (16.1 miles) of double track; it will be equipped with alternating-current track circuit and main and distant daylight signals. The line is electrified, the traction current being 1 500 volts D. C.

The installation of automatic block on the Madrid - Saragossa - Alicante Lines dates from the beginning of 1924. This year block working will be instituted on the section from Barcelona to Mataró (29 km. = 18 miles). This system has been extended successively to the four lines which converge on Barcelona, lines over which the general traffic of the main line is carried and also the very important and ever increasing traffic of the suburbs. Between Madrid and Villaverde (7 km. = 4.3 miles) there is also an installation of automatic block. The installation on the North of Spain Railways dates from 1927, and comprises the section Madrid - Posuelo which should eventually be continued up to Villalba. Below are indicated the length of line and the number of automatic signals in the installations already carried out and those projected:

		North of Spain.	Madrid-Saragossa-Alicante.
Kilometres (miles) of double track with automatic block :	Working. . .	9 (5.6)	107 (66.5)
	Proposed. . .	29 (18.0)	35 (21.7)
Number of automatic signals :	Working. . .	11 (6.8)	172 (106.9)
	Proposed. . .	53 (32.9)	45 (28.0)
Average length of track per signal :		1 100 m. (3 608 feet)	1.310 m. (4 290 feet)

We would remark that the programme and the carrying out of installations on the North of Spain and the Madrid-Saragossa-Alicante Companies present, in spite of their having been worked out independently, considerable analogy in their method and their fundamental points. These analogies are significant for they reveal the high degree of perfection in the technique of automatic block which leads to nearly uniform solutions similar to the typical solutions of American practice. In view of this similarity, and for the sake of brevity, we detail only the programme and the features of the automatic block adopted by the Madrid-Saragossa-Alicante Railway because we have at our disposal for this work a great number of facts from which to form an opinion.

The programme which this Company laid down comprised the following essential conditions:

1. To permit the succession of trains at full speed at 5-minute intervals.

2. In the stations through which the trains pass, or stop without leaving the through road, to obtain complete automaticity of the signals in such manner that the station staff would not have to concern themselves with their operation.

3. The adoption for the purpose of simplicity and clearness of one single method of signalling for the block and for the protection of the stations and special points; and to this end to give to each signal the duty of maintaining the spacing between the trains and of protecting entry into the station, authorizing departure, etc.

a) *Signals and rule of the road.*

To realize this programme three-aspect signals have been adopted as being those which best fulfil the required conditions of spacing, speed, distance between the stations, etc., as is explained hereafter in Chapter V.

In the first installations of automatic block the semaphore signal with upward movement of the arm was adopted, but in the later installations colour-light signals have been employed because of their recognized advantages (Chapter III). Figures 6, 7, and 9 show the types of daylight signals and semaphore signals employed.

In some main terminal stations (Barcelona Terminus) where there are difficulties, because of the small space available between the tracks, in erecting posts for the starting signals, three-position ground signals have been adopted of the type shown in figure 10.

The indications for the arm or daylight signals mentioned are as follows:

— *Stop:* Arm horizontal or red light.

— *Prepare to stop at next signal.* Arm inclined upwards 45° or green light (this will be replaced later by a yellow light).

— *Continue at normal speed up to next signal:* Arm vertical upwards or white light (to be replaced later by a green light).

For automatic signals on the open road, according to the most usual practice in these installations the *permissive rule* is followed. The stop signal may be passed after a stop of three minutes (four minutes on the North Railway), at reduced speed up to the following signal, the aspect of which must be noted by the driver. On the other hand, block signals which protect simultaneously stations, turn-outs, etc. give *non-permissive* indications and may not be passed when at danger, except when they are out of

Fig. 9. — Three-position automatic signal covering entry into a station. On the right, post on which transformers are mounted (Spain, Madrid-Saragossa-Alicante Railway).

order; and then only by formal permission of an official authorized for the purpose.

The distinction between *permissive signals* and *absolute signals* is determined during the day time by the form — pointed or rectangular — of the free end of the semaphore arm. To obtain the same distinction at night in the semaphore signals, and by day as well as by night for daylight signals, a separate lamp is mounted on the signal post about 2 m. (6 ft. 7 in.) below the main signal. If this signal is *absolute*, this lamp is placed immediately under that of the signal, but if the signal is *permissive* it is placed obliquely on the other side of the post.

This indicator lamp has another rôle (hence its name), that of indicating the presence of the signal in case the signal lamp has gone out. The North Company

has chosen a moonlight white light for the indicator lamp for daylight signals. On the Madrid-Saragossa-Alicante Lines this light is red. This colour has been adopted in spite of the theoretical objections which might be raised to the permanent presence of red in a signal which can give indications other than that of « stop », because this red light is the most convenient, on the principle that every signal extinguished is equivalent to « danger » and compels a stop in cases where the signal lamp has been accidentally extinguished. Further the indication lamp is like a position light, and its characteristic place in relation to the signal light distinguishes it perfectly from the latter and allows it to be easily

Fig. 10. — Three-position ground starting signal (Spain, Madrid-Saragossa-Alicante Railway).

recognized or identified, whereas if the white light were used to indicate « line clear » it might be confused with the ordinary lamps used for lighting.

The rule of *line normally clear* has been adopted except for the slotted *absolute* signals which protect special points. It is considered that in automatic signalling the *line clear* rule is the more rational and that the *signal at danger* rule does not give any better security, particularly when the motor is directly coupled to the axis of the arm which clears upwards, by which any risk of danger from snow or ice is eliminated. With the *signal at danger* rule there are required for the automatic clearing of the signals on the approach of the train more relays, more contacts in action, and more line wires, which complicates the installation and increases the risk of failure; the saving of electric

current in the *danger* rule is not important when alternating current from an industrial centre is used at low prices. The *line clear* rule allows the linesman when patrolling the line to discover by the fact of the signal being at danger the most common defects; broken connections, blown fuses, defective installation on the track, broken rails, etc. On the other hand, with the *signal at danger* rule, a failure only becomes noticeable by trains being held up for an undue length of time, a contingency which can only result in disorganisation of the traffic as a whole.

b) *Block spacing.*

To allow a five-minute succession, sections of about 2.3 km. (1.35 miles) were sufficient; nevertheless much shorter sections have frequently been put in, necessitated by the distance between stations. The distance between the starting signal of one station and the home signal in the next (signals which act always as block positions) has been divided into two, three or four sections, approximately equal, except when, for reasons of visibility, some variation is necessary. The sections thus vary between 1 000 to 2 500 m. (3 280 to 8 200 feet).

Figure 11 gives an idea of the block spacing employed and shows what is done in the case of two stations P and Q, a short distance apart (2 km. [1.24 miles] for instance), where in spite of the short distance which separates them an intermediate block section has been put in. This facilitates slow or stopping trains following one another at short intervals. Without this signal B 3 the starting signal B 1 would act as the distant signal of B 3; consequently if a train should be in section Q, the train following it would have to leave P with the signal at « caution » and would lose time, which does not happen if the intermediate signal exists.

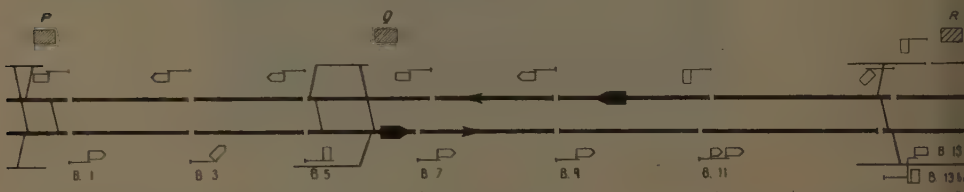


Fig. 11. — Division of the line into automatic block sections.

These signals are placed in front of the insulating joints which divide the sections without « over-lap » or headway, in such manner that they are put to danger at the moment when the first axle of the train passes the insulated joint next to the signal. The fact that the signal goes to danger before the whole of the train has passed it, and that the driver can see this action at the moment of passing it, has not been considered objectionable, and it has not been thought necessary to avoid it by complicating the installation or adding a simple « over-lap ». On the contrary it is thought that it gives to the driver a sense of security in being able to actually verify the proper working of the signals.

The block is not broken within the stations but continues along the direct or main line, so that the portion of the road lying between the home and starting si-

gnals of the station constitutes a block section.

Therefore a train standing on the main line keeps the home signal at danger until it leaves the station or until it is diverted on to another road, thus leaving the main line unoccupied.

Stations of some importance allow entry on to one or several branch roads directly by the facing points, and for these roads the block is interrupted in the following manner : According to the explanation given in Chapter I the home signal is a splitting signal, with arms or lights for each direction (see fig. 6). All these signals are semi-automatic, that is to say they are controlled at one and the same time by track circuits and by a lever in the cabin. The arm or signal corresponding to the diverted road goes to danger automatically directly the train passes it, and cannot clear again until the signal lever in the cabin (interlocked with the points) has been put to « danger » and then returned to « clear », that is to say that only an operation of the lever can permit the entry of a train. In this manner, in spite of the « line clear » rule, it is impossible for a second train to run on to the same branch road without permission from the station. Further, in certain important stations, the loop lines on to which passenger trains are received are also provided with track circuits throughout their length in order to make it impossible to clear the home signal when these roads are occupied.

c) *Fitting up and working.*

In the plan for installing the block system on the Madrid-Saragossa-Alicante Railways the following leading ideas were taken into consideration : — the adoption only of methods and of apparatus which can be recommended from long railway experience; — the necessity of requiring in the apparatus, and especially in the relays which are the basis of the system, the greatest possible perfection with every guarantee against failure, — to consider that this guarantee of good working gives more regularity in service and at least the same degree of safety, than the complications in working and construction which arise when one is systematically distrustful of the apparatus.

The block works by means of track circuits fed by alternating current at 52 cycles. The track relays are of the motor type with three positions and double windings, the one fed by local current, the other by the track circuit. The use of three-position relays has facilitated the suppression of all wires between the signals on the line thanks to which not only the cost but also the failures due to breaking or crossing the wires, have been reduced. Figure 12 shows the typical circuits and how the positions of « caution » or « line clear » are obtained with the aid of an arm circuit breaker connected with each signal which reverses the poles of the current feeding the track circuit of the preceding signal. In this manner the rotor of the relay turns to right or to left according to the polarity; and the 45° or the 90° positions of the signal are thus obtained by the respective contacts. When daylight signals are employed the reversing of the polarity of the track circuit is obtained by means of a reversing relay, in acordance with the circuits shown in figure 13.

However, on the lines to be electrified with 1 500-volt traction current the arrangement « without line wires » has been abandoned. It is known that the inductive connections which have to be employed in place of insulated joints can act as auto-

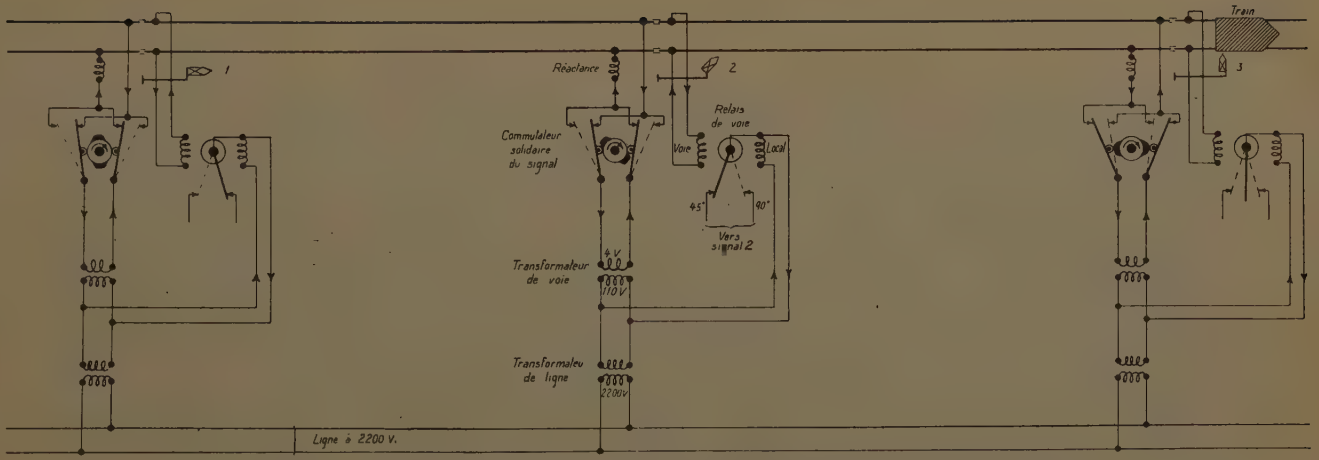
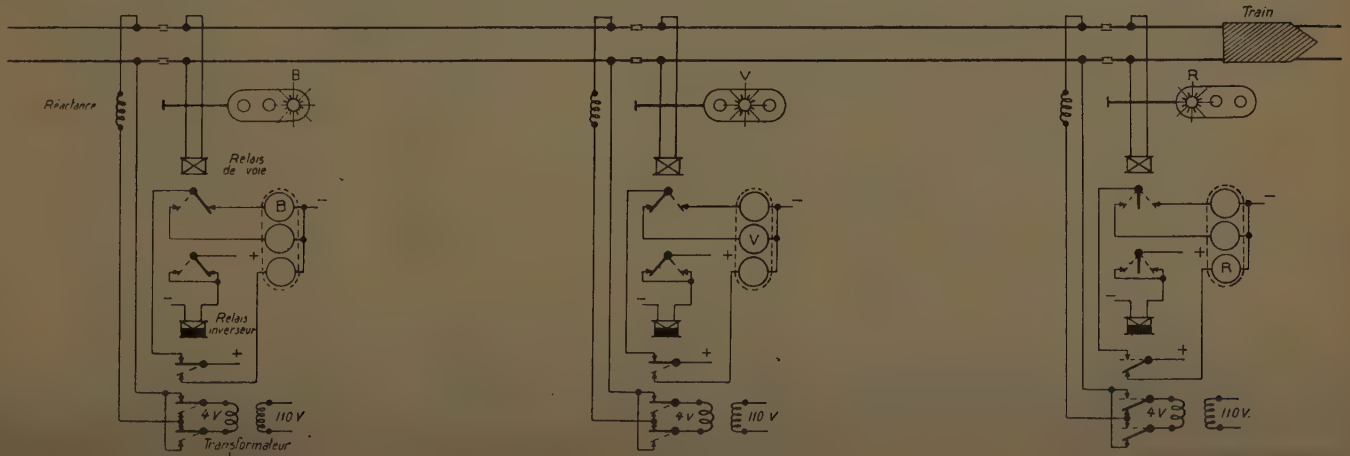


Fig. 12. — Automatic block working. — Typical circuit with three-position semaphore signals.

Explanation of French terms: Commutateur solidaire du signal = Arm circuit breaker. — Ligne à 2200 volts = Supply at 2200 volts. — Réactance = Reactance. — Relais de voie = Track relay. — Transformateur de ligne = Line transformer. — Transformateur de voie = Track transformer. — Vers signal 2 = Toward signal 2.



transformers in the event of a fracture in the rail joint, which might cause a signal to go to the « caution » position instead of to « stop ». For this abnormal position to arise with non-inductive insulated joints, it would require a simultaneous defective working of the *two adjacent insulated joints*. This coincidence of a double failure is highly improbable with joints well designed, well made and also well preserved; and it is for this reason that the system « without wire » has been accepted on non-electrified lines. During the six years in which the installation has been working no breakdown of the insulation has occurred in an insulated joint.

In the stations the following programme has been carried out :

a) Before the home signal can clear, all the points situated on its main road, and on those which may direct a movement towards it, must be locked, thus assuring free circulation of the trains over the said main road.

b) *Approach locking* and sometimes *route locking*, that is to say that the points cannot be thrown on the approach of a train, even if the home signal is put to danger. The object of this condition is to prevent a distant signal or home signal being untimely put to danger by the station after having been sighted by the driver, and thus enable a shunting movement which might become dangerous in such conditions.

c) The approach of the trains is automatically announced at each station.

Figure 14 shows the typical circuits employed to carry out the programme described. The apparatus employed is an electric lock, an indicator and a slow release mechanism.

The electric lock, of the General Railway Signal Company's standard type, is coupled with the route lever, the king lever, or the signal lever, according to the system existing in the cabin.

The movement from « line clear » to « line occupied » is made in two steps. In the first, the lock contact puts the signal to danger. This is « proved » by the signal contact (sometimes also the 45° position of the preceding signal is proved) as soon as the signal is at danger, and sections I and II (approach locking) and III (route locking) are free, the relays of the approach indicator and that of the lock are energised, and the latter raises the armature with the locking piece, and allows the lever to be put into the final position « signal at danger ». In this position the interlockings of the points, barriers and lock bars are released.

The approach indicator on being de-energised (entry of train into section I) rings a bell and keeps a red lamp alight as long as the road is occupied.

The hand screw release allows the approach locking to be cancelled when, a train arriving at the home signal, it is imperative to operate the points in special cases, for instance, to shunt a train part of which is standing in section II. But, for reasons of safety, this action is so delayed that the fixed time interval to which the apparatus is set (usually from two to four minutes) is between the moment when the signal goes to danger and that when the points are released. This time allows the possibility of stopping, or of announcing its presence, to a train against which the home signal has been untimely put to danger, in order to carry out a movement incompatible with its entry into, or passage through a station.

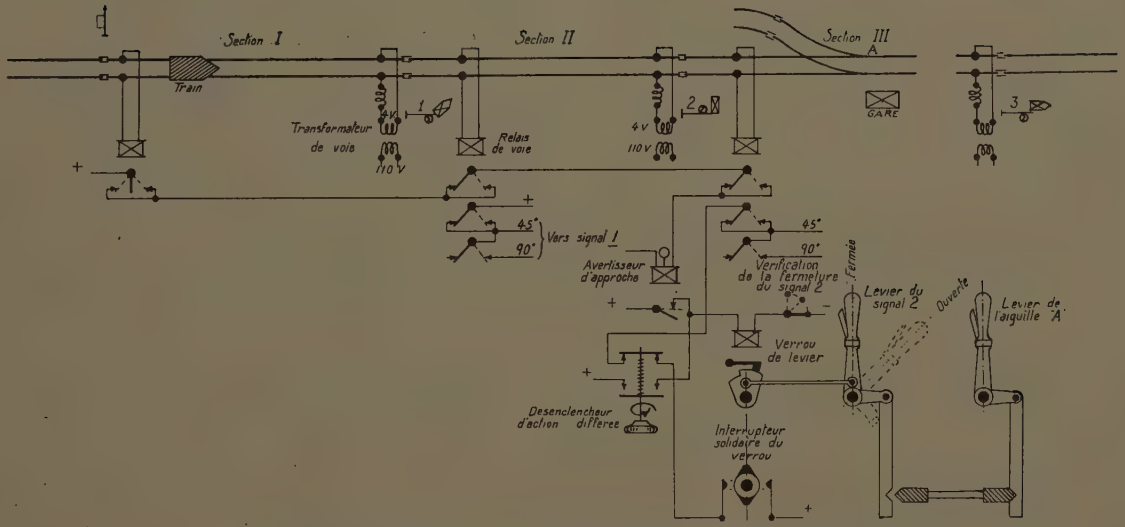


Fig. 14. — Automatic block working. — Typical circuits in connection with a station.

Explanation of French terms: Transformateur de voie = Track transformer. — Avertisseur d'approche = Approach indicator. — Désenclencheur d'action différée = Hand screw release. — Interrupteur solidaire du verrou = Lock contact — Levier du point A = Lever of point A. — Levier du signal 2 = Lever of signal 2. — Relais de voie = Track relay. — Vérification de la fermeture du signal 2 = Signal proving contact (signal 2). — Vers signal 1 = Toward signal 1. — Verrou du levier = Lever lock.

In order not to make this report too long, we will not describe in detail the apparatus and arrangements adopted by the North of Spain and the Madrid-Saragossa-Alicante Railways, and will content ourselves with stating that the whole have been supplied by the General Railway Signal Company. The insulated joints, which are of such importance for the proper working of these installations, are those of the Weber system. They have given excellent results both on the North as well as on the lines of the Madrid-Saragossa-Alicante which has not been the case with other types tried by the North of Spain.

For block working and signal lighting the current is taken from an industrial supply and distributed by monophase line at 2 200 volts. The radius of action of the sub-stations in which the 2 200-volt power is stepped down is about 35 km. (21.7 miles).

Continuity of service is assured by connection with other industrial sources at fixed points along the line, which automatically come into service if the current from the section feeding the installation should fail. Further, at certain suitable locations on the line, three reserve sets with petrol motors have been put in, which also start up automatically should the industrial current fail.

The average power required for the whole of the automatic block installations on the Madrid-Saragossa-Alicante Lines, which together comprise 107 km. (66.5 miles) of double track and 172 signals (138 semaphore and 34 daylight) is 14 kw. 43 % of this is required for lighting the signals, which are permanently alight.

The cost is 0.15 peseta per kw.-hour, or a *total daily cost* (track circuits, signal operation and lighting) of 50 pesetas in round figures, which is equal to a cost for power of 0.29 peseta per signal per day.

For the maintenance of the block installation 16 men are employed, including electricians and their assistants, which represents 0.74 man-hour per day and per signal.

During the six years which has elapsed since the installation was put into working, the results of the exploitation of automatic block on the Madrid-Saragossa-Alicante Railways are completely encouraging. That is why these installations are being extended, notwithstanding that sometimes the density of the traffic does not actually call for them. Safety has been increased to such an extent that on the lines provided with automatic signals no other accidents have occurred except those caused by signals being passed through obvious disregard of their aspects. The most numerous class of accidents, due to forgetfulness, or to mistakes in signalling on the part of the personnel at the stations has been eliminated. All this has lightened the work of the personnel and considerably reduced their responsibility and anxiety regarding the safety of the trains. In effect, so long as the traffic is not upset (regular running of the trains and normal order of succession) the automatic block has enabled the abolition of « lines clear » demand and « train on line » signal.

Thanks to the signals being normally at « clear » the signalmen need not operate the signals so long as the train does not leave the main line and, consequently, no points need be set (a very frequent occurrence in small intermediate stations) and this has at times enabled a reduction in the number of signalmen. In the aggregate, the reduc-

tion of actual work in the stations by the adoption of the automatic block has reached approximately 12 %. It is evident that the resultant saving in personnel does not cover the cost of the specialised staff required for the upkeep of the installation; but this saving is of importance if one takes into account the personnel which would have to be employed for the service of the newly established block positions in the open road with any system of manual block.

As to irregularities in the working of automatic signals only cases of signals going to danger have occurred. The case of a signal which should be at danger assuming the wrongful position of « caution » or « line clear » has never been observed.

The number of times that a signal has gone to danger wrongfully, and its relative proportion, in one year is as follows :

Annual aggregate of the signals which have incorrectly gone to danger	190
Number of signals in service	172
Proportion per signal . . .	1.1
Average number of movements per year and per signal .	48 000
Proportion of faults (wrong danger aspect) per 100 000 movements	2.3

The proportion of 2.3 per 100 000 movements is very small compared with those which are known on other European Railways. In the Metropolitan Railways on the contrary still smaller averages are shown (Metropolitan of Paris: 0.6 per 100 000 movements). But the conditions of working are very different and less severe.

The causes of the failures observed are classified as follows :

Theft and breaking of rail connections	14.3
Blowing of high or low tension fuses	43.1
Failure of the local power supply and damage to the high tension line	22.1
Short circuiting of the rails by sea or by rain	11.2
Various or unknown causes . .	9.3

The high proportion of failures through blown fuses is due to their corrosion by atmospheric action, which is very rapid seeing that an important portion of the installation is so near to the sea that on windy and rough days the covers of the apparatus are splashed by sea water. A high proportion of the short circuits discovered is due to the action of sea water which sometimes reaches the lines.

CHAPTER V.

Some reflections regarding the number of signal aspects, and final conclusions.

Regarding the number of signal aspects, as has already been stated, it was not possible to reach a unanimous agreement at the London Congress.

The final statement 1 which was approved by the Congress was worded as follows:

« 1. — The Congress notes that certain Administrations operate lines with heavy traffic and with mixed traffic by using only « stop » and « caution » signals with two positions. Others prefer

three-position semaphores and yet others consider a fourth position indispensable.

« In these circumstances, the Congress considers that signalling systems should be further examined and experimented with in accordance with the ideas of each line and that it would be advisable to put this question on the agenda for the next Congress... »

We believe that the experience of the last five years has not brought to light any new fact which might justify a change of opinion on the part of those who champion 2, 3 or 4-aspect signalling respectively.

It is no doubt just as well that rejection or approval of one particular type is not called for, since any one of them might be an adequate solution for the particular features of operation.

In justification of this opinion we cannot put forward any arguments or reasons beyond those already well known.

We will, however, try to present our own views systematically, and we trust any didactical turn which they may involuntarily take, will be pardoned.

One word in regard to the question of designation. We believe that one should no longer speak of « positions » but of « aspects » because this last word is as appropriate for board or semaphore signals as it is to daylight signals, whereas these latter, having no visible movement, cannot be said to assume « positions ».

A rational system of signalling ought to have very clear and definite aspects; and as far as possible let us examine what should be a necessary and sufficient series. « *Stop* » and « *continue at normal speed* » are the fundamental aspects. Running towards facing points always requires, or only for a loop line (according to the safety regulations adopted), a reduction of speed : hence the need for an aspect « *pass at reduced speed* » or of its equivalent « *entry by loop line* ». That is all, from the point of view of straight-forward instructions.

With rapid transit, however the « stop » order must always be given to the driver at braking distance (deducting or not the range of visibility). Hence the signals called « *distant* » with their aspects « *prepare to stop at next signal* » and « *signals ahead clear* » (1).

It is not as necessary to have the aspect « *proceed at reduced speed* » on a distant signal if there is within sight a signal which calls for a speed reduction or which indicates the loop line at the point protected. But there is a tendency to give this indication at a distance and consequently one must be prepared for the aspect « *prepare to pass at reduced speed* » or for its equivalent « *prepare to run on to the loop* ».

Finally, the general custom is to indicate the aspect of the starting signal by means of the « home ». But strictly speaking these indications are equivalent to those of any distant signal, and for this reason they should not be regarded as a new aspect.

To sum up, the fundamental indications given by the signals for the succession of trains on the line, entry to, and passage through stations, are reduced to six : three positive and three distant. However, it must not be deduced

(1) Where absolute block is not in force, another function is assigned to the distant signals, *viz.* that of protecting a train situated between the distant signal and the main or shunt signal; then the procedure laid down is more restrictive (proceed cautiously, prepare to stop at the first obstruction).

from this that six indications are necessary.

The question as to how many indications out of the six may be necessary at any particular point on the line is to be considered. This will depend on the concentration or not at this point of the functions of the distant signal and the main signal, or in other words, of the relative position occupied by the signals of these two categories. As one knows, this relative position depends on the length of the block sections and the braking distance, and on that account, we will now examine the methods of signalling with two, three, and more than three aspects.

Two-aspect signalling. — When the length of the sections is very great compared with the braking distance, the distant signal is independent and situated in front of each block signal (diagram *a*, fig. 15). In such circumstances, two-aspects are necessary and sufficient in each signal, *i. e.* the appropriate method is two-aspect signalling.

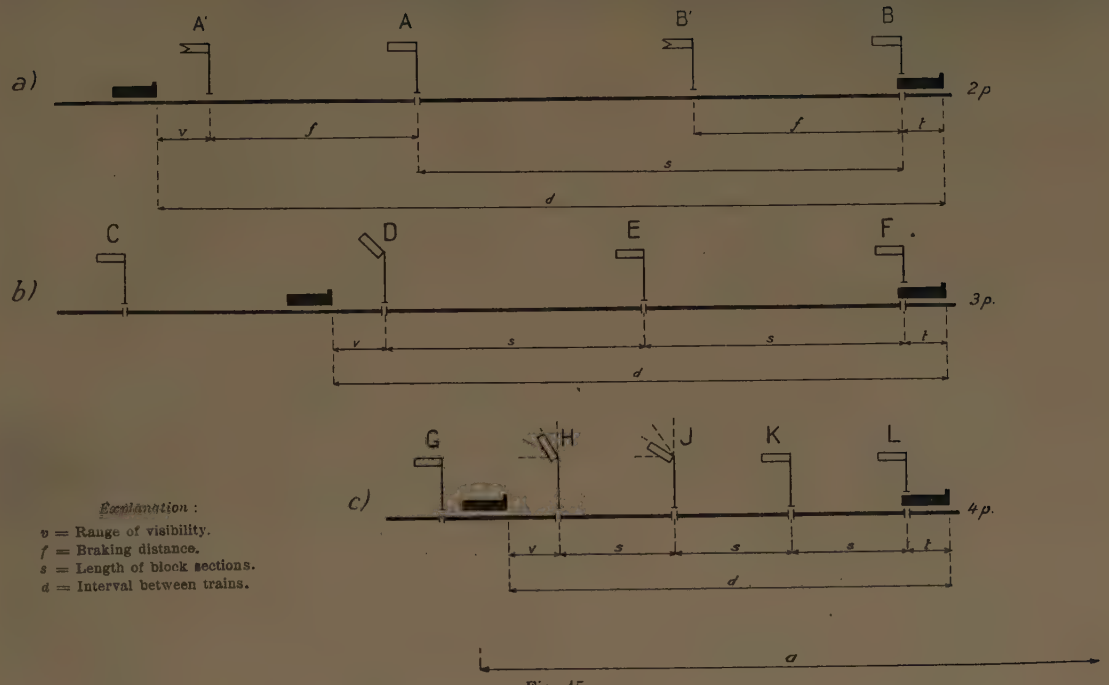
In this category are lines where only the stations are block positions without intermediate positions, an interval between the trains shorter than the distance betwen the stations not being necessary. If three-aspect signals were used on these lines, the starting signal at each station would also be the distant signal for the « home » at the next station, which, as will be easily understood, would give rise to delays or to an excessive spacing apart of the trains.

In the case of diagram *a*, to obtain the same spacing, *d*, with three-aspect signalling, it would be necessary to have an intermediate position between A^1 and B. *i. e. to shorten the sections.* This is not to say that the number of signals would be increased or diminished, *but the number of block positions would be augmented,* for each three-aspect signal would become a block signal; on the other hand, by employing two-aspect signals, a signal and its distant — that is to say two signals — are controlled from one single position. Consequently, *if the block is not automatic* two-aspect signalling is more economical in staff than three-aspect, if the interval between trains allows of block sections much longer than the braking distance.

In order to be able to compare easily the different signalling systems, we indicate for each of them in the table on page 1193 the relations which exist between the braking distance, the length of the block sections, and the intervals between trains, relations arrived at in the following manner :

With two-aspect signalling (diagram *a*) in order that a train following another at the shortest possible distance may maintain its speed, it is necessary that, at the moment of arrival at the distance v of good visibility in front of the distant signal A', the driver shall find this signal already « clear »; for this, the first train must by then have completed passing B, so that by clearing section A-B signals A and A' can go to « line clear ». The distance v can be reduced by the use of automatic signals, which operate without loss of time, but it must be greater with manual block which is slower in operation.

The interval d at which trains may follow each other in relation to the length s of the block sections, of the braking distance f, of the length of the trains t, and of the range of visibility v will be $d = v + f + s + t$. The length s of the block sections in relation to the in-



Explanation :

v = Range of visibility.
f = Braking distance.
s = Length of block sections.
d = Interval between trains.

Fig. 15.

terval desired will be : $s = d - (v + t + f)$.

The minimum spacing at normal speed which can be obtained with two-aspect signals corresponds to the area within which the block sections s are only the braking length f, in which case A and B' are side by side. Consequently, the shortest possible interval will be $d = 2f + v + t$. But in the area where $s = f$, it is more convenient to use three-aspect signalling next referred to.

Three-aspect signalling. — When the length of the block sections is equal to or a little greater than the braking distance, the block signal and the distant signal for the next signal ahead are side by side.

In this case the three-aspect signal replaces advantageously the two-aspect combination of these two signals, without it being necessary to increase the number of block positions; Economy and simplicity is thus obtained and further the reading of one single signal is easier and clearer than that of two signals joined together or a short distance apart. In such circumstances the superiority of three-aspect signals is undoubted.

With three-aspect signalling (see diagram *b*) in order to obtain an interval d between trains running at full speed, the length of the block sections should be $s = \frac{d - v - t}{2}$ and, the minimum spacing obtainable being the braking distance f, will correspond to the case when the block sections will be reduced to the least possible value $s = f$. The value of this spacing will be : $d = 2f + v + t$.

Four-aspect signalling. — If, in order to increase traffic capacity, it is necessary to have a still shorter spacing between the trains than that which has just been indicated, *i. e.* if $d < 2f + v + t$, the block sections must be shorter than the braking distance. Consequently the indication « next signal at danger » can no longer be given by the preceding signal. It will be necessary to give it *two sections back* by means of the second signal behind that which calls for a stop (see diagram *c*). Hence the necessity of having in each block signal four distinct aspects by means of which the state of three sections ahead can be ascertained. These four indications are :

1. Proceed at normal speed (three sections ahead clear).

2. Approach next signal at reduced speed (two sections clear).

3. Proceed at reduced speed, signal ahead at danger (one section clear).

4. Stop.

Although these four aspects may owe their origin exclusively to the rapid sequence of trains and can be considered as line signals it may be remarked that they can also be used for signalling in stations and even employed for certain special indications for instance, to indicate the passage on to a loop line at reduced speed and to repeat this indication at a distance. Therefore it may be assumed that the four indications cited, properly used, can suffice to give all the fundamental indications requisite for the signalling of rapid transit lines, and which, as we mentioned at the beginning of this chapter, comprise three definite orders (Stop; pass; pass at reduced speed) and their three relative « distant » signals.,

It is easy to see that of the dual combinations of these six indications, those which

have one meaning and one application in railway practice are only four, and correspond exactly to the indications given by four-aspect signals.

According to that, four-aspect signalling throughout is necessary when the intervals between the trains require shorter block sections equal to or a little greater than the braking distance $f > s \geqq f : 2$. Proceeding as in the previous cases, we get $s = (d - v - t) : 3$, and the minimum interval with block sections equal to half the braking distance is $d = \frac{3}{2} f + v + t$. The characteristics of the three systems are given in the following table. We include also the formulæ for five-aspect signalling, simply as a matter of curiosity as this type of signalling has neither been employed nor proposed up to the present, and we do not believe that it offers anything of practical interest.

Type of signalling.	Length of block section suitable for each type.	Length of block section for an interval d.	Minimum spacing allowed for each type.
2 positions	$s > f$	$s = d - v - t - f$	$d > 2f + v + t$
3 id.	$s \geqq f$	$s = \frac{d - v - t}{2}$	$d = 2f + v + t$
4 id.	$s \leqq f$ $\geqq 1/2\, f$	$s = \frac{d - v - t}{3}$	$d = 3/2\, f + v + t$
5 id.	$s \leqq 1/2$ $\geqq 1/3\, f$	$s = \frac{d - v - t}{4}$	$d = 4/3\, f + v + t$

The above table shows the cases in which 2-, 3- or 4- aspect signals are required, according to the spacing of the trains. The type of signalling is determined directly the interval between trains and the braking distance are fixed. Nevertheless, this latter proviso, « braking distance », should not be taken too literally. It should be assimilated to the distance at which it is convenient to give the aspect « next signal at danger », which distance varies on different lines according to the factor of visibility and the margin of safety within which the braking distance is calculated.

Up to now, in studying the question of the number of signalling aspects, we have not made any reference to their physical form (boards, semaphores or daylights) because these questions can, if need be, be treated separately. In figure 15, semaphore signals are shown for the simple reason that their aspects are more easily drawn ; but no pre-possession whatever for their use is intended.

Owing to their construction, board signals can only give two indications, but semaphore and daylight signals can be also used as two-aspect signals, so that all three serve equally well for this type of signalling.

Semaphore signals have the advantage of giving during the day a positive indication of « line clear » because their arms are not effaced like the boards. But this objection disappears when the boards are fixed and placed on posts (German, Norwegian and Yugoslaw railways, etc.).

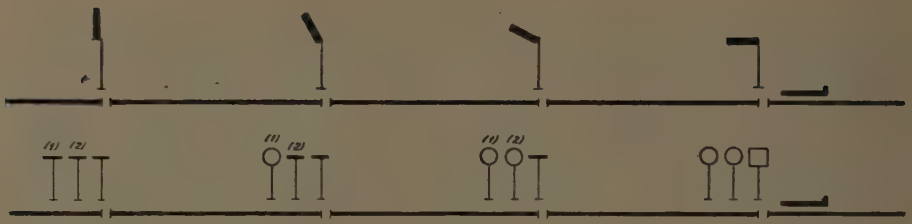


Fig. 16.

From the point of view of visibility we consider there is not much difference between the two types, except when very large semaphore arms on very high posts are used as on the German Railways, for instance; in this case the visibility is greater than with the board signals, which have not these characteristics.

Three-aspect signalling can be obtained by semaphores or daylight signals. The upward movement of the arm is preferable for three-aspect semaphores. It increases the visibility of the « line clear » (arm vertical) and on the other hand the arm returns to « stop » by gravity without special counter-weights.

For four-aspect signals we consider the daylight signal preferable. The daylight signal can give all the aspects desired at a given point, with this special feature that only one aspect is visible at any moment, the others being effaced. The semaphore arm can also give four sufficiently characteristic aspects (45° downwards, horizontal, 45° upwards, vertical). But the mechanical operation as well as placing the signal at « danger » by gravity is difficult to accomplish.

One final remark regarding multi-aspect signals. Some out-and-out advocates of two-aspect signals have maintained that by increasing the number of signals of this type and giving to each of them a well defined application, the same result can be reached as by reducing the number of signals and giving them a greater number of aspects. Certainly, with two-aspect signals it will be possible to obtain the three and four-aspect signalling shown in figure 15. But in our opinion it will always be simpler, safer and more convenient to look at a single signal on which one indication only is visible, corresponding to the most restrictive indication shown by each of the different two-aspect signals which would be necessary to replace it. If for instance we take the case of the four-aspect signalling described previously, we see that in order to give with two-aspect signals the same orders to the driver, we should have to employ at the beginning of each block section the three following types of two-aspect signals; a « stop » signal and two « distant » signals, one to announce the reduction of speed and the other the stop according to the following scheme (fig. 16).

We do not believe there can be any doubt as to the absolute superiority in this case of the single signal over the use of the three signals required to replace it.

SUMMARY

We do not believe it necessary or actually possible to achieve a uniform type of signalling in the different countries

by recommending as superior to the others one particular system. For this reason we will confine ourselves to summarising some of the principles which appear to dominate or prevail in the actual technique of signalling and which by reason of their somewhat abstract character are not special to one type of signal and can be applied in so far as they are fundamental whatever may be the aspects of the signals adopted.

We consider that the experience gained during the last five years only confirms the spirit of the opinions reached on this same question at the 10th session of the Congress (London 1925). These opinions should be maintained (with the exception of the first on account of its temporary character) and can be in any case enlarged and completed by those which arise from the following considerations :

— On rapid transit lines every « stop » signal should be repeated at a sufficient distance to assure the stop under the most unfavourable conditions of visibility and of braking.

— For facing points to turn-outs from the main road and at the entry to stations, the use of a « distant » signal is to be recommended in order to advise the driver of the route given by the points or — which is practically the same thing — to advise him of the reduction of speed necessary if he is to take the branch road.

— With signals given by coloured lights (indications at night of board or arm signals, and daylight signals) a tendency towards the following improvements is observed :

a) The suppression of the continuous white light as the signal for « line clear ».

b) Tendency to avoid the use of the same red light for the « danger » aspect in both distant and stop signals.

c) When for certain aspects two lights are used of the same colour or of different colours a desire to avoid in the case of the eventual extinction of any one of the two lights that the other shall not give by itself a less restrictive order than that which corresponds to the two lights together.

— When at one and the same point it is necessary to give to the trains more than two-aspects or distinct orders, the use of a multi-aspect signal is preferable to that of several separate signals which give diversely restrictive orders.

— All three types of signalling, — two, three and four-aspect — are applicable to rapid transit lines. The minimum interval between trains required by the traffic, and the characteristics of working in relation to the braking, and the distance at which the stop signals should be repeated, determine the most suitable type of signal in each case.

— Daylight signals are those which best suit four-aspect signalling, and the most appropriate lights for these signals in accordance with the third decision of the London session are : red (stop), two yellows (pass signal ahead at reduced speed), one yellow (signal ahead at danger), green (line clear).

— The extension is noted of the use of colour-light day signals because of the advantages which they offer as much from the point of view of visibility and reliability in working as from that of control, and of ease and simplicity in carrying out the most complex working programmes. The limitations to their use

are only to be found in the need of having a sure supply of power at a low price, and of the first cost of installation when these signals are to replace an already existing system of signalling.

— The extension of automatic block installations with A. C. track circuit, when it has been thought necessary to increase the coefficient of safety, is also noted. The tendency is towards simplification in working methods which, without diminishing safety, shall reduce to a minimum the delays due to failures and irregularities.

[385. (07 & 385. 586]

REPORT No. 4

(Germany)

ON THE QUESTION OF THE METHODS FOLLOWED IN TRAINING OF STAFF, PROFESSIONAL, TECHNICAL AND ORDINARY WORKING GRADES (SUBJECT XVI FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1).

by Dr.-Ing. Bruno SCHWARZE,

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Figs. 1 to 20, pp. 1218 to 1247.

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CHAPTER I.

General.

§ 1. — General aspects of training and education on the Deutsche Reichsbahn.

In the last few years the outlay incurred by all great German and foreign transport undertakings in connection with their staff has increased to a much greater extent than the expenditure on materials. In the year 1927 the Reichsbahn expenditure on the staff amounted to 61 %, and on materials to 39 % (in round figures) of the total outlay, while the corresponding figures for 1928 were 66 % and 34 %. These are remarkable figures; variations occur according as the annual outlay on materials is more or less restricted; but the expenditure on the staff always amounts to from 60 % to 66 %.

The « human element » in industry is a problem of much greater importance nowadays than in former years. It is impossible nowadays to reduce the total expenditure of a great railway by a reduction in the wages or salaries of the individual workers; on the contrary an increase of the latter is more probable.

Hence it is essential that the money expended on the personnel should be productive of the best possible results. This can as a rule be more readily achieved by raising the efficiency of the individual than by seeking to increase his merely physical output, at any rate in those undertakings in which the men have hitherto worked hard. Experience shows that in the long run, output and intensive work cannot be increased above a certain point and that apart from general social considerations the result is a considerable increase in ill health and accidents.

Whereas in earlier times of economic growth, attention was mainly concentrated on perfecting machines and installations, nowadays we are faced with the necessity of improving the efficiency of the second and much more important factor, the worker. There is still great scope for this improvement both from the economic and the practical point of view; the amount hitherto expended for this purpose barely reaches 0.025 % of the total expenditure on the personnel, and not even 0.015 % of the total outlay; thus it is a comparatively very small amount. The actual figures are given in Chapter II, § 17.

To achieve lasting results it is necessary to work on a carefully thought out plan, to provide an organization specially adapted to the conditions of the undertaking and to utilize to the full all the modern methods of effectively imparting knowledge which have recently been evolved at the universities and technical schools and in the engineering societies. For example the introduction of cinematography, the use of lantern slides, and of graphical methods of presentation in teaching. It is of importance to keep in touch with these developments and to exploit everything that can possibly contribute to the training of the railway staff. It is one thing to draw up a programme of instruction and, in practice, quite another and more difficult problem to assign proper limits to the use to be made of it. Only so much energy should be demanded of the individual official or workman as is necessary to enable him to perform his service intelligently, easily and economically. But every effort should be made to secure the complete assimilation of this programme established by experts and practical men. To this end also good organization is essential.

Put shortly, these are the main considerations which guided the Reichsbahn in the development of their educational system. The fact that the post-war difficulties have been to some extent overcome and the number of accidents has been reduced, is in part due to the greater efficiency of the individual, a result aimed at by the above-mentioned educational system.

Besides this there is another advantage. By means of systematic training which employs the most modern methods, it has been possible to reduce the time of training in individual cases. Further particulars will be found in chapter II, § 13. There is no need to dwell on the possibilities of economising by these means, especially if only such persons are admitted to training as have been proved suitable by psycho-analytical tests.

§ 2. — The officials of the Reichsbahn.

The majority of the officials cannot be dismissed from the service and are subject to pension on retirement. The matter is governed by the act of 30 August 1924 dealing with the State Railways and their employees. In accordance with these laws the German State Railways have issued a set of bye-laws. It would take too long to go into details. It is

however essential to discuss the different grades of officials, when describing the methods of teaching and training. But as their names and functions are different in different countries we furnish below some explanation of the titles of the officials of the State Railways, which are quoted as examples in chapter I, § 5.

At the head offices (General Management) of the Reichsbahn, which correspond to the Ministry of Transport in other countries possessing Government railways, there is a director (Reichsbahndirektor) allotted to each main branch of the Administration. The different Reichsbahn managements work under the instructions of the General Management. Each of these managements is divided into different departments e. g. Traffic, Operation, Finance and is controlled by a chief entitled Director at the Reichsbahn (Direktor bei der Reichsbahn). The members of these Departments are railway high councillors (Reichsbahnoberräte) and railway councillors (Reichsbahnräte). The office work is controlled by these higher officials and is done, according to the difficulty of the task by superintendents (Amtmänner), technical and non technical senior inspectors (Oberinspektoren) and senior clerks (Obersekretären); for simpler jobs, ordinary clerks (Sekretären), assistants and operating assistants (Assistenten and Betriebsassistenten) are employed.

Under the managements are the district offices for operation, traffic and locomotives respectively. Such a district office (Amt) is managed by a senior official (Oberbeamte), who is either a man with University training or one with practical experience only, with the rank of Reichsbahnoberrat or Reichsbahnrat. He disposes of a staff which is similarly constituted to that of a Directorate (Direktionsbureau). For the carrying out of the work on the line itself, each section has a number of subordinate centres such as railway stations, permanent way sections, locomotive repair shops, roundhouses, etc. The most important subordinate centres are managed by a superintendent (Amtmann), the others by senior inspectors and senior clerks and the smaller railway stations with a smaller staff, by clerks, assistants and operating assistants. These again have under them the classes of employees mentioned in chapter I, § 5, e. g. engine drivers, guards, foremen, etc.

Goods officials (Ladebeamte) belong to the goods department and superintend the handling of the goods in the sheds. In the permanent way section, gang foremen (Rottenführer) and inspectors (Rottenmeister) work under permanent way supervisors (Bahnmeister). These are men who have gangs each of about ten men in order to carry out permanent way repairs. Foreman shunters and shunters attend to the marshalling of goods trains.

In the more important places, the points and signals are worked by leading signalmen (Stellwerkmeister) or pointsmen, in less important places by pointsmen only. Rolling stock examiners (Wagenmeister) look after and test the vehicles of incoming trains as to their proper running condition, e. g. examination of couplings, brakes, axles, heating and lighting, etc.

All sections of the line are inspected daily or every two days by track watchmen (Bahnwärter) who examine the condition of rails and sleepers and see that there is no obstacle on the lines. The opening and closing of gates at level crossings at points where there is much traffic or risk of accident is done by gatekeepers.

For maintenance purposes workshops

are provided which are under the direction of a senior official (Oberrat or Reichsbahnrat). The staff is similar to that of a directorate (Direktion).

Young officials of the higher offices, such as railway councillors (Reichsbahnräte), railway assessors (Reichsbahnassesoren) and building engineers (Reichsbahnbaumeister) sometimes act as assistants in the section offices and in the repair works.

The foregoing general indications may enable a comparison to be made with the corresponding staff of similar organizations in other countries.

§ 3. — Craftsmen and labourers of the Reichsbahn.

In the wages agreement of 11 July 1924 all fully employed men are classified as workmen (Arbeiter) of the Reichsbahn, except those which are officials or salaried employees. In this way apprentices in the shops, probationers from the higher schools and from secondary schools do not belong to the class described as workmen.

According to their occupation the wages grades are subdivided into: auxiliaries acting as clerks, employees in the operating department, permanent way maintenance men and workshop labourers.

The greater part (56 %) of the personnel of the Reichsbahn consists of wages grades. It is therefore a matter of considerable moment to ascertain to what extent their usefulness can be increased by education and training. A glance at the spheres of activity of the individual classes of workmen shows where special demands are made upon the skill and knowledge of the workmen and hence where instruction provided by the Reichsbahn will prove most useful.

The auxiliaries who are chosen from the workmen to fulfil clerical duties must be suited for their particular service and be specially trained for that duty. Similarly the men employed as workmen in the railway operating department proper, must have special knowledge of that class of work especially as they are frequently called upon to deputize. Again the men employed exclusively on maintenance work are required to have experience of mechanical appliances and the application of up-to-date workshop practice, and unless they are suitably instructed they will be unable to perform their duties satisfactorily.

The men in the shops are divided in skilled men (Handwerker), semi-skilled men or helpers (Werkhelfer) and unskilled labourers. In order to run the shops on scientific lines the railway must possess or create a nucleus of high class foremen and craftsmen. Skilled men are often called upon to carry out duties which are quite outside the sphere of their regular work; thus among the skilled men there must be trained piece work rate fixers, work inspectors, times checkers, etc.

On account of the rearrangement of the shops the work of the semi-skilled men has become more varied and important. Nowadays trained skilled men are not used to the same extent as formerly for the simpler jobs; instead unskilled men are employed who are given a short course of training for their special work. For this purpose special methods suited to the psychology of the learner are adopted in industry. After adequate tests these methods have been introduced on the Reichsbahn.

Apart from a short period of training the unskilled men in railway workshops do not in general require special courses of instruction. In this case directions given before commencing the work usually suffice.

The education of the rising generation of skilled workmen in the shops and schools for apprentices is of great importance for railway work. The practical and theoretical training of these apprentices is reviewed in chapter II, § 14.

§ 4. — Total staff and number of persons to be trained.

The Reichsbahn employed on an average in the year 1928 :

	Regular.	Extra.
A. *Officials :*		
Groups 10 to 17 *a* . . .	210 181	5 083
Groups 6 to 9 *a*	89 873	377
Groups 5 and under . . .	3 452	128
Total . . .	303 506	5 588
Extra officials	5 588	
Officials in training service	1 432	1 503
Staff councillors (Beamtenräte)	71	
Total number of officials	310 597	
B. *Agents (Angestellte)* . .	492	
C. *Auxiliaries carrying out office work*	76 122	
D. *Wages grades :*		
a) Operating department men	122 342	
b) Permanent way men .	92 347	
c) Shopmen :		
1. Craftsmen	68 778	
2. Unskilled men . . .	26 449	
d) Apprentices	3 195	
e) Probationers from the higher and secondary schools	253	
f) Senior traffic men (Betriebsräte) , . . .	88	
Non-officials, total	390 066	
Total number employed 1928	700 663	

Under normal conditions 4 % of the staff is to be completed by recruits every year. Hence about 12 000 men have to be taken on every year and trained for the duties of those officials whose places they take. In addition there is the number of officials who in the course of their careers have to undergo further training.

From the foregoing it will be evident how great is the task of the railway education department, merely from the point of view of numbers.

§ 5. — Regulations for the training of middle and lower class officials.

The whole body of officials, excluding a small number of the higher management, is divided into 17 groups for purposes of pay. Participation in the instruction for service work is regulated according to which of these groups the man belongs and the arrangements are made with reference to this fact. The following selected examples will illustrate the grouping.

Group 1. Reichsbahn director (Reichsbahndirektor), Director at the Reichsbahn (Direktor bei der Reichsbahn).

Group 2. Reichsbahn high councillor (Reichsbahnoberrat).

Group 3. Reichsbahn councillor (Reichsbahnrat).

Group 4. Chief superintendent (Reichsbahnoberamtmann).

Group 5. Superintendent (Reichsbahnamtmann).

Group 6. Technical and non-technical senior inspectors (Oberinspektor).

Group 7. Technical and non-technical senior secretaries (Obersekretär).

Group 8. Chief clerk (Kanzleivorsteher).

Group 9. Senior clerk, engine driver, shop foreman.

Group 10. Head guard.

Group 11. Technical and non-technical assistant, leading signalman, carriage and wagon examiner, reserve engine driver.

Group 12. Foreman loader, foreman shunter, permanent way gang foreman, signalman.

Group 13. Locomotive fireman, rail motor coach driver.

Group 14. Assistants in the operating department.

Group 15. Passenger guard (ticket collector), shunter, pointsman, machinists.

Group 16. Office auxiliaries (messengers, etc.).

Group 17. Flagman.

The majority of the officials belong to groups 7 to 15. By way of illustration, we give for each of these groups a resume of the most important rules regarding the midst from which they are selected, regarding the grade of education required, concerning psycho-analytical examinations, physical fitness, general education and also with reference to one or two other matters.

A. — Technical and non-technical officials of the higher section of the middle class.

Outdoor and indoor services

a) Senior technical secretaries (specialised in civil and mechanical engineering and surveying).

1. *New entrants :*

a) Civilian candidates. — Professional school students (technical probationers of the Reichsbahn;

b) Reserve candidates (technical probationers of the Reichsbahn);

c) Technical officials of the lower salaried groups rising by promotion (Aufstiegsbeamten).

2. *School education :*

a) Professional school students, civilian candidates: Certificate of removal to the Obersekunda (Upper fifth form) of a high school having nine classes; certificate of competence from a high school having six classes; certificate of competence of a technical high school giving a course of at least five terms and recognized by the Reichsbahn;

b) Reserve candidates : Adequate general education and certificate of competence from a recognized technical professional school;

c) Promotion officials: Adequate general education and sufficient preparatory technical education.

3. *Practical training :*

a) Civilian candidates : Two years work in a shop corresponding to the service chosen or alternatively in the survey department;

b) Reserve candidates : Thorough training in a handicraft according to the class of work to be taken up;

c) Promotion officials : Generally as for reserve candidates.

4. *Psycho-analytical examination :* No.

5. *Physical requirements :* General fitness for service in the classes for building and machine shop work. (Sight without glasses for the machine shop class, with glasses for the building work class). Special physical fitness is not required for the survey work staff (sight test allowed with glasses).

6. *Preliminary examination* (1) : Civilian candidates (technical scholars : none. Reserve candidates : yes (in order to prove their general education).

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(1) The preliminary examination serves to determine the preliminary education which is required for entry into the chosen official career. Candidates who hold a certificate which is recognized by the management. in place of the preliminary examination, are exempted.

Promotion officials : yes (in order to prove their general education and technical preliminary training).

7. *Professional training :* Civilian and reserve candidates, 3 years; promotion officials, where practicable less than 3 years.

8. *Examination :* Formal.

9. *Appointment (outside budget = remunerated on capital expenditure for new works,* etc.) : Civilian and reserve candidates : Technical (or non technical) senior secretary in the survey department).

10. *Appointment (regular = within the scope of the budget) :* Technical (or non technical) senior secretary in the Survey Department (Group 7).

11. *Promotion:* To the rank of technical senior inspector or survey senior inspector (Group 6), or superintendent (Group 5/4).

b) *Non technical senior secretaries.*

1. *New entrants : a*) Civilian candidates (civilian supernumeraries);

b) Reserve candidates (Probationers of the Reichsbahn);

c) Reichsbahn assistants and senior clerks, males and females (promotion officials).

2. *School education :* Civilian supernumeraries : ready for Oberprima (Upper sixth) of a public higher school having 9 classes (provisional regulation); probationers and promotion officials of the Reichsbahn, equivalent general education.

3. *Psycho-analytical examination :* Yes.

4. *Physical fitness :* for male beginners, fitness for outdoor service (sight test without glasses) : with female beginners, fitness for indoor service (sight test with glasses).

5. *Preliminary examination :* Civilian supernumeraries : no; remaining applicants : yes.

6. *Training :* Civilian supernumeraries, 3 years; probationers, 2 years. For promotion officials no formal training but, if desired, preparatory occupation is given at the most 2 years.

7. *Examination :* formal.

8. *Appointment (outside regular budget) :* Civilian supernumeraries and probationers of the Reichsbahn as senior secretary (outside budget).

9. *Appointment (regular) :* Senior Reichsbahn secretary (Group 7).

10. *Promotion :* Up to the rank of senior inspector (Group 6).

11. *Promotion :* Up to the rank of superintendent (Group 5/4).

B. — **Senior clerks, locomotive drivers, and shop foremen.**

(Salary group 9.)

a) *Senior clerks.*

The posts are filled by promotion from the officials appointed as assistants, so that the rules governing salary group 11 are in force here.

b) *Engine drivers.*

1. *New entrants : a*) Skilled workmen of the Reichsbahn (fitters, smiths, coppersmiths);

b) A limited number of firemen (unskilled workmen).

2. *School education :* Elementary school.

3. *Psycho-analytical examination :* Yes.

4. *Physical requirements :* Fitness for outdoor service (sight test without glasses).

5. *Preliminary examination :* No.

6. *Training :* 3 1/2 years (2 years bench work in a locomotive workshop and 1 1/2 years on the road as fireman).

7. *Examination :* Craftsmen : no special form for fireman; craftsmen and firemen (not craftsmen), formal examination for engine driver.

8. *Appointments (outside budget) :* —

9. *Appointment (regular) :* for craftsmen as locomotive drivers in reserve (salary group 11).

10. *Promotion :* to locomotive driver (salary group 9).

c) *Shop foreman.*

1. *New entrants :* Craftsmen from the Reichsbahn.

2. *School education:* Elementary school.

3. *Psycho-analytical examination :* No.

4. *Physical requirements :* No special fitness for outdoor service laid down (sight test without glasses).

5. *Preliminary examination :* Yes. Evidence is required among other things of knowledge of simple arithmetic, calculations for contract work with vulgar and decimal fractions, knowledge of the metric system of weights and measures, calculation of the areas of rectangular and circular surfaces and of the volumes of bodies bounded by rectangular, circular or spherical surfaces.

6. *Training :* 7 years as crafstman or leading hand, of which at least 5 years must be spent in a railway workshop, one year special training as foreman.

7. *Examination :* Formal.

8. *Appointment (outside budget) :* —

9. *Appointment (regular) :* as foreman (salary group 9).

10. *Promotion :* —

C. — **Guards.**

(Salary group 10.)

1. *New entrants :*

a) Railway workers;

b) Reserve candidates (probationary guards).

2. *Schooling :* Elementary school.

3. *Psycho-analytical examination :* Yes.

4. *Physical requirements :* Fitness for outdoor service (sight test without glasses).

5. *Preliminary examination :* Yes.

6. *Training :* 1) *for preliminary appointment* (guard) for workers whose career has not yet been decided, either three months employment working on a station, or on shunting work, on the goods shed or in workshops or 6 months work on the maintenance staff, and in addition one month's training as guard on goods train; for reserve candidates, four months; in both cases a further four weeks' training before employment on passenger trains.

2) *For promotion* (head guard) 9 months responsible work as passenger guard and three months preparatory work as head guard.

7. *Examination :* For the first appointment : informal, for promotion, formal.

8. *Appointment (outside budget) :* —

9. *Appointment (regular) :* As guard (salary group 15).

10. *Promotion :* To head guard (salary group 10).

D. — **Technical and non technical Reichsbahn assistants.**

(Salary group 11.)

1. *New entrants :*

a) Civilian candidates (engineering aspirants);

b) Reserve candidates (technical and non-technical probationers);

c) Technical and non-technical officials of the lower salary groups (promotion officials).

2. *Schooling and practical preparatory education* : For civilian and reserve candidates, complete elementary school education; in addition :

a) For civil engineering and machine construction work either three full terms (18 months) at a technical school and two years practical work in the particular subjects, which are of value for railway service, or learning a handicraft suitable to the line to be taken up and one year's work as draughtsman, or 3 to 4 years' work as draughtsman;

b) For survey work the corresponding technical school education or a regular apprenticeship and one year's work as surveying assistant, or five years' work as technical assistant in the surveying service;

c) For lithographic work, service in the laboratory, photographic work, etc., suitable training and one year's practical work;

d) In the case of technical and non-technical promotion officials (Aufstiegsbeamten) the management of the Reichsbahn decides whether the man's previous education suffices or not.

3. *Psycho-analytical examination* : For technical work, no; for non-technical posts, yes.

4. *Physical requirements* : For non-technical posts, physical fitness for outdoor service is required (sight test without glasses); for technical posts, physical fitness not necessary (sight test with glasses).

5. *Preliminary examination* : Yes.

6. *Training* : For technical posts, 2 years; for non-technical posts, 1 year.

7. *Examination* : Formal.

8. *Appointment (outside budget)* : Technical aspirants as Reichsbahn assistants.

9. *Appointment (regular)* : As Reichsbahn assistant.

10. *Promotion* : To senior clerk.

E. — Officials of the goods handling department (goods guard, goods foreman).

(Salary group 12.)

1. *New entrants* :

a) Workers in the goods sheds and luggage departments, also other workmen of the Reichsbahn; the latter are put on to the goods shed or luggage service, after their career has been determined;

b) Reserve candidates (probationary goods guards).

2. *Schooling* : Elementary school.

3. *Psycho-analytical examination* : Yes.

4. *Physical requirements* : Physical fitness for outdoor service not laid down (sight test with glasses).

5. *Preliminary examination* : Yes.

6. *Training* : For workmen, 21 months occupation in goods sheds or on luggage work (this requirement can be fulfilled before application for the job) and actual training, three months; for reserve candidates, six months.

7. *Examination* : Informal for the first job (goods guard); formal for promotion (goods foreman).

8. *Appointment (outside budget)* : Reserve candidates as goods guard.

9. *Appointment (regular)* : As goods guard (salary group 15).

10. *Promotion* : To goods foreman (salary group 12).

F. — Firemen.

(Salary group 13.)

1. *New entrants :* Workmen on the Reichsbahn, chiefly engine cleaners and men employed on coaling locomotives.

2. *Schooling :* Elementary school.

3. *Psycho-analytical examination :* No.

4. *Physical requirements :* Fitness for outdoor service (sight test without glasses).

5. *Preliminary examination :* No.

6. *Training :* 1 1/2 years (12 months' occupation as helper and six months' service on the foot-plate).

7. *Examination :* Formal.

8. *Appointment (outside budget):* —

9. *Appointment (regular) :* As locomotive fireman (salary group 13).

10. *Promotion :* To locomotive driver; this is only possible to a restricted extent.

G. — Assistants in the operating department of the Reichsbahn.

(Salary group 14.)

1. *New entrants :*

a) Male persons :

1) Civilian candidates : workers of the Reichsbahn; in the event of shortage of suitable workers, persons not employed by the Reichsbahn may be chosen;

2) Reserve candidates (probationers for the Reichsbahn operating department);

b) Female persons : in proportion to the workers.

2. *Schooling :* Elementary school.

3. *Psycho-analytical examination :* Yes.

4. *Physical requirements :* For males, physical fitness for outdoor service (sight test without glasses); for females, fitness for indoor work suffices (sight test with glasses).

5. *Preliminary examination :* Yes.

6. *Training :* 10 months.

7. *Examination :* Informal.

8. *Appointments (outside budget):* For probationers as assistants in the operating department.

9. *Appointment (regular):* As assistant in the operating department (salary group 14).

10. *Promotion :* The assistants in the operating department are used principally to fill the posts of non-technical Reichsbahn assistants.

H. — Pointsmen.

(Salary group 15.)

1. *New entrants :*

a) Workmen on the Reichsbahn;

b) Reserve candidates : Probationary pointsmen.

2. *Schooling :* Elementary school.

3. *Psycho-analytical examination :* Yes.

4. *Physical requirements :* Fitness for outdoor service (sight test without glasses).

5. *Preliminary examination :* Yes.

6. *Training :* For workmen, 3 months; the men, before they apply for the job, must as a rule have worked for 1 year, or at least 6 months on railway maintenance work; for reserve candidates (probationers) 6 months.

7. *Examination :* Informal for first appointment (pointsman), formal on promotion (signalman).

8. *Appointment (outside budget) :* Reserve candidates as pointsman.

9. *Appointment (regular) :* As pointsman (salary group 15).

10. *Promotion :* To signalman (salary group 12).

I. — **Office auxiliaries (messengers, etc.).**

(Salary group 16.)

1. *New entrants :*

a) Reserve candidates;

b) Workmen on the Reichsbahn.

2. *Schooling :* Elementary school.

3. *Psycho-analytical examination :* No.

4. *Physical requirements :* Fitness for outdoor service not required (sight test with glasses).

5. *Preliminary examination :* No.

6. *Training :* Six months.

7. *Examination :* Formal for first job.

8. *Appointment (outside budget) :* Reserve candidate as office auxiliary (messenger, etc.).

9. *Appointment (regular) :* As office auxiliary (messenger, etc.) (salary group 16).

10. *Promotion :* To leading messenger (salary group 16 with increase of pay and pension).

K. — **Watchmen.**

(Salary group 17.)

1. *New entrants :*

a) Reichsbahn workmen, chiefly from permanent way maintenance service.

b) Reserve candidates.

2. *Schooling :* Elementary school.

3. *Psycho-analytical examination :* No.

4. *Physical requirements :* Fitness for outdoor service (sight test without glasses).

5. *Preliminary examination :* No.

6. *Training :* Six months.

7. *Examination :* Formal.

8. *Appointment (outside budget) :* Reserve candidates as track watchmen.

9. *Appointment (regular):* As track watchmen (salary group 17).

10. *Promotion :* —

These particulars may suffice as characteristic examples for other official appointments and careers in the Reichsbahn. It is clearly shown that in every case a training period is provided for and what length of period is considered necessary in the individual cases. It is necessary to differentiate between two distinct types of training. First the beginner when applying for a particular career must be able to show that he has had a *general preliminary training* suitable for the service in question. For example, in the case of foremen an extended period of activity as craftsmen or leading hand is called for. The Reichsbahn does not discriminate regarding the particular details of this work; it is only necessary to give evidence of the results of such employment.

The case is different as regards the *professional training*. This training is carried out on a pre-determined plan in such a way that the beginner is gradually given different official and service appointments, in which he obtains practical instruction and thus acquires the necessary knowledge and practice in connection with his job. As an example the training for Reichsbahn assistants may be quoted. These men have to familiarize themselves by 12 months of practical work with the duties of an assistant in the operating and goods department.

§ 6. — **Regulations for training as applied to the groups of higher class officials.**

A. — **General.**

The higher grade officials are in general given higher posts and are either

employed at Headquarters (General Management), at the managing of Directorates (Direktionen), where they are appointed as Departmental heads, Presidents, Members, Superintendents or Assistants. In a few cases engineers holding degrees are employed on special terms on the staff as advisers for specially difficult work. First we give some figures:

At the end of 1927, there were officials of the upper grades.

In addition :

1. Civil engineering department.	1004
2. Mechanical engineering department	580
3. Administrative services	465
4. Architects	77
5. Chemists	7
6. Surveyors	20
7. Officials with preparatory training	295
Total. . .	2448

Accordingly, 2 153 of the 2 448 officials of the upper grades will have had a higher school (University) training, while 295 officials have either been posted from the former State Railways of Würtemberg and Baden or have been promoted from the middle class of officials on account of special merits. Promotion then is made as a rule from chief superintendent (Reichsbahnoberamtmann), Superintendent (Amtmann) or senior inspector, to Reichsbahn concillor (Reichsbahnrat) with employment as special councillors (Dezernent) or Director of a division (Amtvorstand).

It will be seen that the number of higher grade officials is extremely small being only 0.94 % of the total personnel. This number will in time be still further reduced after certain special problems, due to post-war conditions, have been overcome and when by re-arrangement certain smaller districts have been unified and the special councils (Dezernate) that are not fully occupied, withdrawn in consequence. The immediate saving of money is of less importance; the saving in the work of management and supervision is not to be overlooked.

The officials who have not been promoted from the middle class are required to complete a full course of studies and to pass the Government examinations; thus legal officials must qualify as barristers or assessors whereas the technical officials must pass succesfully the Government examination for *works supervisor* (Regierungsbauführer) and for *civil engineer* (Regierungsbaumeister). Preference is in general given to applicants who pass as a minimum the second examination with at least the mark « satisfactory ».

The acceptance and training of officials who have completed their studies is for the present still governed by the rules applied to the former railways of the different States. In the region formerly governed by the Prussian-Hessian State Railways, acceptance is controlled by the Board of Management, which took the place of the Ministry. In Bavaria it is arranged by the District Management in Munich and in the realm of the former Saxon and Würtemberg State Railways, through the President of the Directorate at Dresden and Stuttgart. For Oldenburg and Mecklenburg the acceptance is arranged direct by the Central Administration in Berlin.

As an example the rules for the region covering the Prussian-Hessian lines of the German State Railways are given in the following.

B. — Civil and Mechanical Engineering Departments.

1. *Education* : Leaving certifcate of a recognized higher educational institution

having nine classes (*Gymnasium, Realgymnasium, Higher Realschule, Reform school*).

2. *Practical work :*

a) For civil engineers; 6 months on important construction work;

b) For mechanical engineers; at least one year as laid down in part IV, paragraph 6. The practical work can in part be done during the higher school vacations.

3. *Studies :* Eight terms at a technical high school and passing examination as « Diploma engineer ».

4. *Application for training as Reichsbahn works supervisor :* The application for training must be sent in not later than six months after gaining the diploma and must be addressed to the Board of Management of the Deutsche Reichsbahn Gesellschaft in Berlin, W. 8, Voss-Strasse, 35.

5. *Particulars required :*

a) Details of career;

b) School leaving certificate;

c) Leaving certificates of the technical high school at which the applicant has studied;

d) Pass certificate for the preliminary examination for diploma;

e) Pass certificate for final examination for diploma;

f) Document granting title as diploma engineer;

g) Official certificate of character;

h) Official medical certificate;

i) Proof of the necessary means for the applicant's support for 4 years; this proof must be officially certified;

j) Certificates of previous occupations;

k) For diploma engineers who go in for machine construction work, a certificate of the practical work done in a workshop for one year in accordance with the rules for the examination for the diploma (as far as possible all certificates to be in the original).

6. *Training as Reichsbahn works supervisor :* The training is carried out at the different service posts, in the directorates and at Central Administration.

7. *Grants :* Grants in support of maintenance in accordance with the rates fixed by the State may be given to some of the works supervisors. The conditions are : satisfactory results in the diploma examination (marks at least « good »), diligence and need of assistance. In certain sections of the training, in which a works supervisor takes the place of another absent employee, pay on a higher scale than the maintenance grant may be allowed.

8. *State examination before the technical higher examination commission : Appointment as Government civil engineer :* Applicants in the Department of machine construction must have had three months service as engine driver, and must pass the examination for engine driver.

9. *Appointment in the service of the Reichsbahn as civil engineer :* The appointment is only made on a vacancy occurring; condition : passing of the diploma and Government examination at the first trial and as regards the Government examination marking must be at least « good ». Preference is given to civil engineers who have studied political economy and are thoroughly capable of speaking and writing a living foreign language.

C. — Administrative Department.

1. *Education :* Leaving certificate of a recognized higher educational institution having nine classes (*Gymnasium, Realgymnasium, Higher Realschule,* « Re-

form » school); in case of need latin will have to be taken up subsequently.

2. *Practical work* : —

3. *Studies* : At least six terms spent in pursuing a regular course of law studies at a University.

4. *Passing of the first Government examination* (barrister).

5. *Training as barrister* : Three years work at the courts, under the Attorney-General and with Sollicitors.

6. *Passing of the second Government examination (assessor)* : Qualification to sit as a judge.

7. *Application for appointment in the service of the Reichsbahn* : A detailed application with full particulars of career and specially the results of the different examinations passed, has to be sent to the Central Administration of the Reichsbahn in Berlin. The official records of the applicant are obtained by the Reichsbahn from the Courts of Justice or the Home Office, so that further particulars on the part of the applicant are not required.

8. *Registration and appointment* : Applicants are only registered on the selected list, who will not have reached their 30th year on the prospective date of appointment and who have passed the examination as assessor at least with distinction.

Assessors who, in addition to the study of the fundamental subjects of political economy, have heard further lectures on the history of political economy, sociology, finance, banking and stock exchange work, etc., that is to say assessors who, in addition to their juridical training, have carefully studied political economy and where possible have wound up with the examination for doctor of political science (Dr. rer. pol.).

Preference is further given to applicants who are capable of speaking and writing a foreign language.

The appointment is made in accordance with vacancy occurring and capability of the applicant, sometimes in a few weeks, generally however only after some months up to a maximum of about two years.

9. *Training* : The assessor is given a year's training in the different services and offices of the Reichsbahn as also in the General Management, in order that he should obtain practical knowledge of railway service requirements, before he is permanently appointed on the staff of the Reichsbahn.

CHAPTER II.

Theoretical training.

§ 1. — Necessity or otherwise.

The practical training in the Reichsbahn as is the case with the majority of other important Railway Authorities, is supplemented by systematic theoretical instruction. Although this feature seems at the first glance to be a natural procedure, opinions differ greatly in the actual execution. Is a theoretical training of railway officials really necessary for the good of the service? Can they not learn their work much better by practising daily the safe handling of signal levers, of the mechanism of a locomotive, the correct method of carrying out structural work or the mastering of despatch instructions than by any sort of teaching? It is true that a man of medium intelligence can learn gradually by the daily round of service how to do this or that job : as for instance to move a number of levers correctly. Unfortunately, the stress of railway service does not everywhere permit of such a gradual and slow method of learning, of

trying and practising on apparatus which has to be continually available for the service. At best it is only the regular processes which take place. The railway official must however be likewise prepared for unforeseen eventualities, which so easily arise under the changing conditions of service. For such cases, a certain elasticity of the man's intelligence is necessary in order that he may be in a position to determine what suitable steps to take. Thus the official must possess a sure mastery of the operations to be performed, even when such cases arise on rare occasions only. Moreover, it is not always possible to employ an offical in the same post. Deputizing, promotions and changes of a structural nature or in the machinery of certain installations bring with them changes in the employment of officials or give rise to new duties. In such cases sufficient qualified staff must be available at short notice. Further, it is important to explain the wording and objects of service instructions which are often very meagre and to impress them firmly on the mind. This cannot be attained without careful instruction; the more complete and the more conscientious the teaching is, the greater is the resulting benefit both from the point of view of efficiency and of the intelligence of the learner. As with a tree, he repays an hundredfold the trouble taken, by bearing ripe fruit.

May not the cost of only one serious accident, due to inadequate training of an official, outweigh the expense of providing adequate training of the staff in the whole of the Reichsbahn area for all the officials for a whole year ? But apart from such extreme cases, every incomplete operation carried out by an insufficiently trained official is always much more expensive, on account of inefficient use of time and material, the resulting delay in the general sequence of operations and of all other work resulting from and dependent on this operation, than the correct, rapid and efficient performance on the part of an official who is really master of his particular duties. Such individual losses total up to an enormous figure with an extensive personnel and the danger is greater inasmuch as the cause is hidden from any inexpert observer who may be judging the matter superficially. Inasmuch as we are considering officials, that is persons, who do not change their occupation later on and whose increased efficiency due to better training is to the permanent benefit of the management, the capital expended is conserved and actually operates for the good of the management of the railway. The *general education* necessary for the profession must, however, be proved *before* appointment; if later on the general education requires supplementing, it is left to the personal diligence of the official to provide this. The necessary instruction must be obtained in private institutions or under the teaching arrangements of the associations of officials and workmen. The arrangements for instruction provided by the Reichsbahn may therefore be limited to the provision of special knowledge according to the career to be followed.

Hans A. Martens, in an essay published in the *Verein Deutscher Eisenbahnverwaltungen* (1922, No. 22, p. 433) on the importance of training and development, points out that the essence of adult training lies in the endeavour to raise the average of the majority as high as possible above the zero line. In view of the small number of years devoted to the training, compared with a period of activity lasting about 35 years, this average would fall at an alarming rate without

the introduction of further training during this period and it would moreover react injuriously by diminishing the demands made even on beginners.

Conversely the average line in an undertaking will tend to rise, if every man co-operates in perfecting himself in his calling and willingly takes advantage of the opportunities offered him for this purpose.

Private industries in Germany possess a system of training and instruction, often excellently well organized. Mention may be made here of the arrangements provided by the Allgemeine Elektrizitäts Gesellschaft, by Siemens in Berlin and by the Rheinische Westfälische Werke directed by Dr. Vögler, among others.

§ 2. — Methods of training and courses of instruction on the Reichsbahn.

Instruction for the training of personnel is either arranged for in periods distributed over a certain time or it is given in the form of a continuous course such as obtains in an ordinary school. With the intermittent periods for instruction the practical training can be arranged to be carried out concurrently with the theoretical schooling. A good example of this is seen in the workmen's schools for apprentices, where the syllabus is carefully arranged to agree with progress in the practical work so that the two really form one instructional unit. Unfortunately the instruction for candidates as officials cannot be so closely fitted in with their practical training. This is due on the one hand to the different stages at which the training of individual candidates commences and also on account of the fact that they do not pass through the different training centres in the same order. The system of service lectures and the school of management are to be included in the teaching which is carried out intermittently. This intermittent instruction is however disadvantageous if it takes place in situations at a considerable distance away so that teacher and pupils have to lose much time and be a good deal on the road, thus incurring at times, travelling expenses. Further, it cannot be denied, that the numerous interruptions in the practical training caused by the intermittent instruction period are sometimes much more disturbing to candidates and even more to the teaching officials than would be the case if the candidate was provided with an uninterrupted series of lectures which would form a complete course.

The system of a continuous course of teaching, which necessitates the students being taken from their service duties, is of material advantage in the fact that the learners are intellectually more intensively absorbed in the subject and are brought into much closer touch with the teacher; this combination has a much stronger influence on the individual and greatly increases the effectiveness of the teaching. Instruction of this type may likewise be suitable for the beginner's school. It is true that it will then be necessary to sacrifice the above-mentioned advantage of fitting in the theoretical instruction to suit the progress in the training of the candidate. It is a question which must be decided in each case, as to which method is to be preferred according to the circumstances. This form of instruction can moreover be adopted in connection with special lectures and special courses, such as are provided for individual groups of officials according to requirements.

Again the question of how to arrange

the instruction to suit local conditions has to be decided according to the particular circumstances of the case. In such cases one must be guided especially by the kind of subject to be taught and the number of students. According to the subjects and the number of students, the pupils belonging to one section, one district or to a still larger unit will be grouped together. In the service instruction 128 (1) therefore the following is laid down for the beginners' school :

The individual courses may be arranged for at a central point or at the seat of the General Management of the Reichsbahn or at a Directorate or at one of the larger service stations. This will be decided by the management of the Reichsbahn in every case in accordance with the economic point of view and taking into consideration the number and location of the beginners, the available teaching staff and the accessories necessary for the instruction.

The Management decides according to the same conditions whether a continuous course is to be provided or whether instruction shall only be given on separate days.

As regards matters taught, the D. V. 128 distinguishes between the following 8 subjects : general management, cashiers, bookkeeping and accountancy, service in the operating department, service in the traffic department, service in the civil engineering department, locomotive running service, workshops, marine department.

The main method of teaching adopted in the schools of the Reichsbahn is :

1. A course with an academic foundation for securing proficiency, as for example for apprentices, high school and middle school probationers.

2. Practical training in the service. The officials must during the preparatory period be thoroughly and practically trained, so that later on when they have to act independently, they will be equal to all requirements of practical service conditions.

3. The schooling course which has to supplement the practical training. By a thorough theoretical schooling the pupil is given a thorough understanding of the reasons for and the requirements of practical service.

4. The psycho-technical learning which is obtained by theoretical and practical schooling in accordance with methods having a psychological basis. The results provided by psycho-technical learning are dealt with specially in part VI.

In the commencement of training the teachers will have to include some educational instruction and, by examples and models, get the personnel to accustom itself to efficient working for economic reasons for the benefit of the undertaking. As auxiliary means for this educative work pictures may serve in which the result of saving and efficiency in small matters have their effect on the working of the whole of the Reichsbahn. The teachers must also endeavour to awake in their pupils a sense of duty and responsibility. This educative task is particularly important for officials of the Operating Department. Further, the Reichsbahn being a public transport undertaking must educate its staff for intercourse with the public.

Instruction is not to be limited to the period of training but must be continued during the individual's occupation, in order that officials may continually be made aware of new matters introduced into the service and can meet the measures taken by the management with corresponding understanding and good will.

(1) Abridged in the following and referred to as D. V. 128 (see chapter II, § 3, D).

An uninterrupted and methodical instruction of the personnel concerned with the Operating Department is for reasons of public safety absolutely necessary; the good results of this are seen in a reduction of the accidents.

§ 3. — **Organization of training and teaching system on the Reichsbahn.**

A. — **Classification :**

In general we distinguish three main groups in the system of educational teaching, according to whether the arrangements are intended principally :

For apprentices, helper-workmen or service beginners (employees being trained for taking a post as an official), or

For officials, particularly those belonging to the operating department, permanent way maintenance and traffic service departments, who are to have important service instructions explained to them and new arrangements brought to their knowledge so as to secure the best possible execution of their duties, or finally,

For officials and workmen, who desire to continue their education independently.

According to the foregoing the groups are as follows :

Group 1 : Service school system;
Group 2 : Service lecture system;
Group 3 : Voluntary education system.

Detailed sub-headings are as follows :

Group I : *The service school system.*

1. *Beginners' school.* — Is a teaching institution for one or more important service posts (stations, shops of the operating department, shops of the permanent way department, freight despatch), arranged in connection with one of the posts for the benefit of service beginners who are in course of training at these posts or in their immediate neighbourhood.

Service beginners of the operating, permanent way maintenance and traffic departments are chiefly concerned.

2. *School of management.* — Classes arranged at a Reichsbahn head office or at the central offices of the Reichsbahn, and worked in conjunction with the respective authority for such service beginners who are employed at this office or at service posts in the vicinity.

Preparation for non-technical and technical office work and the completion of knowledge of special subjects for junior officials of the above-mentioned authorities, are principally considered here.

Note : In the schools for management and service beginners, special supplementary courses may, if required, be given in addition to the systematic courses which are repeated year by year, and more especially :

a) in the case of servants of the railway who have previously had little or no opportunity of attending a school where proper instruction in the service duties could be obtained.

b) when new and important regulations are issued or when technical installations are introduced with which the staff has to be made thoroughly familiar,

c) in cases of unforeseen increases in traffic and heavier operation work, necessitating a rapid training of auxiliary staff.

In addition to these special supplementary courses we have to reckon with such as have to be arranged in isolated cases for the purpose of completing the schooling of beginners, if such should be urgently necessary from the point of view of their efficiency in the service and if the men in question have had

no opportunity elsewhere of obtaining such teaching.

3. *Works school.* — This is a form of instruction provided by the Railway in repair shops, main workshops or subsidiary works for the training of apprentices under service conditions, the subjects being those proper to the regular public advanced training or handicraft schools. This special form of instruction counts as a complete and authorized substitute for the latter. Hence the apprentices are then not required to attend any other public trade school.

Note : If the Railway does not possess such a « works school » and the apprentices attend a public advanced training or trade school, it is laid down that the apprentice is to receive additional tuition in the shops, especially in matters relating to railway practice. This supplementary instruction in the technics of railway work is given the name of « supplementary instruction for apprentices ».

GROUP II : *Service lectures.*

The objects of the service lectures are:

a) to impart a thorough grounding in the knowledge concerning existing regulations and to explain and encourage their practical application.

b) to explain new regulations and arrangements.

The time spent in hearing the lectures counts as service. Officials of the operating department including locomotive men are those chiefly concerned, as also permanent way and traffic men.

All officials, for whom such lectures are arranged, have to take part without exception. In ordrer to make this possible, every course of lectures on service matters which takes place on premises connected with the railway service, has to be repeated several times.

Following each lecture a discussion of the latter takes place.

Note : 1. Included in the lectures are such as are given on special technical or scientific subjects and arranged for the works supervisors of the railway, assessors under training and other officials.

2. In addition to the service lectures, regular discussions can be held as may be directed by the Reichsbahn management for the purpose of explaining important local happenings or installations. Such lectures are given by the heads of departments or their representatives for the benefit of the officials working under them.

3. The staff for the service schools and lecture courses generally consists of railway officials. Where necessary they can be employed as travelling teachers.

GROUP III : *Voluntary educational courses.*

Under this heading may be indicated teaching and educational features of all descriptions for officials and workers with a view to development of personal character, for extending and enlarging their general knowledge and for the completion of their technical studies, the latter having as chief aim an improved position and better economic conditions.

Generally speaking the arrangements under group 3, being made predominantly for the benefit of the participants, are left to be organized by technical and other associations of officials and workers, and in case of need under co-operation of the railway management.

It will be seen that voluntary educa-

tion is placed on an equal footing with the official training. We shall return to this again later on.

B. — Special reporters on training.

Under a number of Directorates there are special reporters (Dezernenten) for the administration of training and teaching arrangements. These have to fulfil, among others, the task of attending to :

a) Matters concerning the entire teaching and training system.

b) Following up the results of examinations.

c) Matters concerning the welfare of juniors.

d) Special matters in connection with apprentices.

e) Psycho-technical matters.

f) Entering into and maintaining relations with other authorities connected with Industry, Handicrafts and Technical School Management.

g) Utilization of appropriate literature, as also

h) Supervision of libraries and magazines, journals, etc. In addition the special reporters for education co-operate with other administrative offices in a number of duties.

The area of the State is divided into ten education districts. In each district a managing directorate is appointed for directing the business of the department.

Educational District No. 1 : *Altona* includes the Reichsbahn directorates of Altona, Hanover, Munster, Schwerin and Oldenburg.

Educational District No. 2 : *Berlin* includes the Reichsbahn directorates of Berlin and Stettin.

Educational District No. 3 : *Breslau* includes the Reichsbahn directorates of Breslau and Oppeln.

Educational District No. 4 : *Dresden* includes the Reichsbahn directorates of Dresden, Halle, Magdeburg and Erfurt.

Educational District No. 5 : *Bavarian group* includes the whole area controlled by the group.

Educational District No. 6 : *Frankfort* (Main) includes the Reichsbahn directorates of Frankfort (Main), Kassel and Mayence.

Educational District No. 7 : *Cologne* includes the Reichsbahn directorates of Elberfeld, Essen, Cologne and Trier.

Educational District No. 8 : *Karlsruhe* includes the Reichsbahn directorates of Karlsruhe.

Educational District No. 9 : *Stuttgart* includes the Reichsbahn directorates of Stuttgart.

Educational District No. 10 : *East* in Frankfort (Oder) includes the Eastern Reichsbahn directorates and Königsberg, and also the Reichsbahn central offices.

The resulting organization is shown diagrammatically in figure 1.

The directorate conducting the business side serves as an information bureau and in a consultative capacity to the Reichsbahn directorates linked up with it.

1. The group reporter (Gruppendezernent) must visit at least every two months every directorate belonging to his district, must be present with the local reporter concerned with teaching and training, at a number of the classes held for officials working in different departments; further, he has to discuss questions of general interest, especially the economic utilization of the arrangements available for teaching, the development of the teaching staff, the arrangement of courses held in common, and

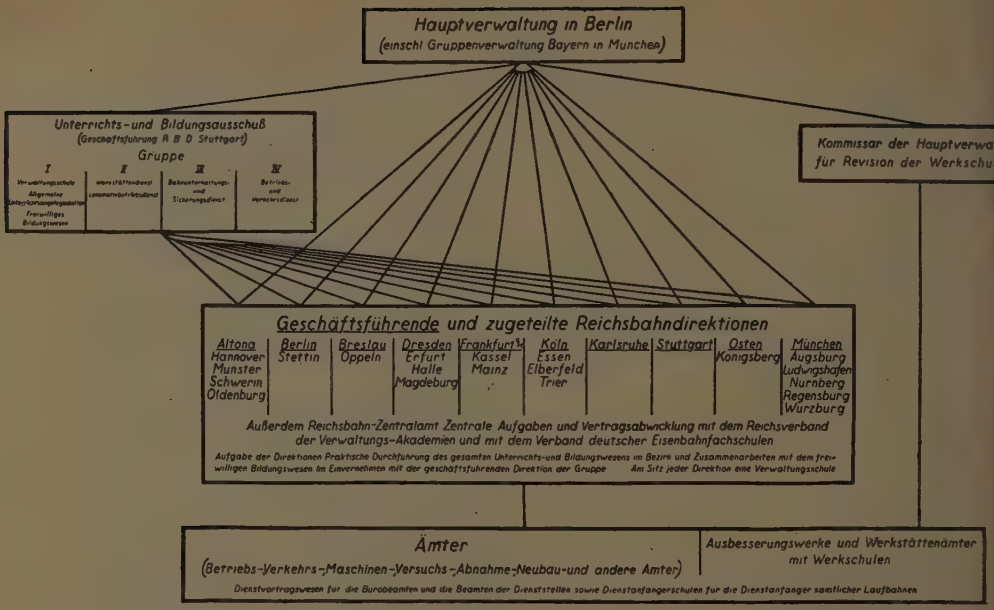

Fig. 1. — Organization of the system of education and training on the Reichsbahn.

Translation of German terms:

Central Administration in Berlin.

(Including the Bavaria group, in Munich.)

Committee on education and training (management by the Stuttgart directorate of the Reichsbahn).

Commissioner of the Central Administration for inspection of techn training schools.

Groups:

I.	II.	III.	IV.
Management school. General matters in respect to education. Voluntary training.	Worshops. Locomotive running services.	Permanent way maintenance. Signals. Safety appliances.	Operating department and traffic department.

Managing and affiliated Reichsbahn Directorates.

Altona	Berlin	Breslau	Dresden	Frankfort	Cologne	Karlsruhe	Stuttgart	East	Munich
Hanover	Stettin	Oppeln	Erfurt	Kassel	Essen			Königsberg	Augsburg
Münster			Halle	Mayence	Elberfeld				Ludwigshafen
Schwerin			Magdeburg		Trier				Nuremberg
Oldenburg									Ratisbon
									Würzburg

In addition, Central Office of the Reichsbahn: General matters and execution of the contracts with the Union of colleges for administrative sciences and the Union of the railway training schools.

Duties of the directorates: Practical application of the education and training system in their respective territories and collaboration with the voluntary training institutions, in agreement with the managing directorate of the group. At the seat of each directorate, a school of management.

Sections.

(Operating, traffic, locomotive running, materials testing, material inspection, new works and other sections.)

Repair works and works sections with training schools.

Service lectures for office clerks and employees of the outdoor services and beginners' schools for beginners in all careers.

the various matters connected with the system of voluntary education.

2. The group reporter must from time to time be invited to ordinary directorate meetings. Here he will suitably, by means of a short address, give information regarding new experiences, arrangements and aids to instruction introduced at other directorates, authorities or private works which are worth imitating, and in this connection the reporter will have an opportunity to discuss matters generally.

3. About once every six months the managing directorate must arrange for a meeting between the Group reporters and those reporters working with the remaining directorates on teaching and training work, with a view to discussing together any important questions of the day. Among other things the occasion is to be used for an exchange of ideas on aids and methods for instruction with a view to extending the utilization of such new ideas and further, if desirable, to consider the question of holding courses in common for one district.

4. Once or twice every year the reporters of the managing directorates shall attend a general meeting of the managing directorate under the chairmanship of the special reporter (Sonderdezernent) from the Reichsbahn central office, which latter will fix the time and place. The object of this meeting is to discuss important questions which may have arisen and which equally affect all districts, matters of secondary importance being left aside. The discussions are to refer especially to the practical carrying out of the directions for instruction, to communicating experiences and arrangements worth imitating, more especially with reference to the economical side of instruction work. Further, the exchange between districts of instruction cars and costly aids to instruction, the economical utilization of central schools by means of systematic and equally divided attendance from all the districts, the arrangements for the technical weeks of the management academy and finally the avoidance of duplicating the arrangements by suitable co-operation of several managing directorates are to be discussed.

5. In respect to each Reichsbahn directorate contained in his territory, the reporter must see that he is always fully informed, as regards :

a) The strength of personnel required for service instruction in the different groups.

b) The number of officials undergoing training and the trained or to be trained reliefs.

c) The arrangements for instruction, instructional apparatus and aids and their application in every case.

d) The courses to be held at the school of management, at the service school for beginners, the organization of service lectures and special service courses, as also special courses in connection with the voluntary training system.

e) The number of trained expert railway teachers, whose capability must be ascertained with special care.

f) Within individual districts, the results of examinations are a good criterion of the efficiency of the local instruction and at the same time afford a means of comparison in this respect between individual directorates. The group reporter must keep himself informed regarding the results of examinations and for this purpose he shall be present at frequent intervals at examinations in

all subjects and for all classes of officials.

The directorates belonging to a group shall hold at the disposal of the managing directorate all the necessary information and data regarding the foregoing.

6. Each managing directorate shall report twice a year on its activities to the Central Administration, that is on the 15th of March and the 15th of September. In this connection it shall, among other things, report regarding the various points enumerated above and shall include statistics and dates of the visits made to the districts. Further, proposals shall, if necessary, be made for such improvements and measures, for which the Central Administration is the responsible authority or which may be suitable for discussion by the Committee on instruction and training.

C. — Committee on instruction and training.

A further important step was the institution in 1922 of a standing committee under the leadership of the Reichsbahn directorate at Stuttgart. This committee examines and discusses measures concerning the system of instruction and training. Its organization and the work it has to do will be apparent from official ordinances which are in part rehearsed below.

The committee is divided into four subject groups, namely :

1. Management school; general matters concerning instruction and system of voluntary training (group I),

2. Workshops and locomotive running service (group II),

3. Permanent way service (group III) and

4. Operating and traffic services (group IV).

Permanent members of the Committee :

Eight officials of the senior service (reporters);

Non-permanent members :

The members of the four subject groups constituted in the following manner :

Group I : School of management, etc. — Two reporters, three officials from the clerical staff, one to be co-opted by the upper council of officials (Hauptbeamtenrat), one by the upper council of operation (Hauptbetriebsrat).

Group II : Workshops, locomotive running service. — Four reporters, one departmental head (Amtsvorstand); one service superintendent (Dienststellenvorsteher), one engine driver co-opted by the upper council of officials (Hauptbeamterat), one workshop employee co-opted by the upper council of operation (Hauptbetriebsrat).

Group III : Permanent way service. — Two reporters, one departmental head (Amtvorstand), two service superintendents (Dienststellenvorsteher) one of whom to be co-opted by the upper council of officials, one permanent way employee co-opted by the upper council of operation.

Group IV : Operating and traffic services. — Four reporters, one departmental head (Amtvorstand) two officials from the clerical staff, one of whom to be co-opted by the Hauptbeamtenrat and one by the Hauptbetriebsrat.

In general the work can be done by the permanent members. On the occasion of extensive consultation 6 to 7 non-

permanent members belonging to different departments and groups are called in. For example, if it is a question of the permanent way that is to be discussed, an inspector or foreman platelayer would be called in or if it is a question of running, an engine driver and a railway station official would be required. The office where the business of the committee is controlled has to look after both the work of the committee as also of the individual groups.

D. — Service ordinance for the teaching and training organization.

The committee issued a detailed service order (No. 128) which was then, after making a few alterations, adopted by the Central administration and introduced officially in the whole area of the Reichsbahn. These regulations regarding the service schools and syllabus of lectures now form the basis of the practical working of the system.

Part I : *School for beginners.* — Regulates among other things the work to be done, the classes from which the participants are to be drawn, the type of instruction, the questions regarding the teaching staff, school hours, classrooms, auxiliary instructional apparatus, inspection, visiting and completing the courses of instruction. Further, the subject and the matter to be taught are set out in detail and this is done so completely that the text can be used without any further reference for the actual instruction itself. To a great extent success depends on the proper choice in regard to the above-mentioned details. Briefly, every matter must be brought up, of which the official must have unquestionable knowledge in order that he should carry out his duties properly; and further, what is almost more difficult, everything superfluous must be avoided. There is no time for learning superfluities. The officials are to be brought up not as students, but as sound, practical men with an understanding of the problems with which they are faced at the present time.

The subjects include general management, cashier's duties, book-keeping and accountancy, work of the operating department, of the traffic department, the civil engineering work, the locomotive engineering work and ship work.

Part II : *School of management* — is similarly constituted.

§ 4. — Regulations governing participation in professional training.

Service schools and lectures count as working time for those officials and workmen who are obliged to take part in the instruction. Without permission from the supervising office no employee may absent himself from instruction. This rule is necessary in order that the pupils may not be withdrawn from the schools unless there are very urgent reasons. When getting out the time-tables for the men, especially those employed in the running services, care must be taken that they (the men) are really able to take part in the instruction work. This sometimes requires a good deal of thinking out, for it is not possible to fix an unlimited number of hours for classes; for reasons of economy it will be incumbent to see that each class is sufficiently well filled. As regards individual officials it is necessary to check whether he has had the prescribed number of school hours during the month and has not perchance heard the same instruction several times over. If a pupil wishes to be freed from the schools

for personal reasons, he must get leave from the office where he is employed.

§ 5. — Aims and management of the service schools.

Details regarding these basically important questions are to be found in service order No. 128 of the Reichsbahn, which has already been alluded to above (1).

According to this the aim and object of the teaching is to visualize and to co-ordinate the impressions and experiences existing in the minds of the pupils, in order thereby to lay the foundation for a clear understanding, so that all conceptions which are necessary for the life and calling of the pupil can be defined and fixed. Further, the instruction is to have an educative effect, whether in virtue of the knowledge gained or by its conscious or unconscious effect on the pupil himself. The repeated enforcement of clear conceptions or notions should enable the pupil to carry out his work in an intelligent and conscientious manner, and also fit him to carry on his work independently. The value of knowledge lies in its application, and not in learning alone.

The results of the teaching must be commensurate with the time given to it, otherwise the latter is wasted. Success depends principally on the manner in which the teacher understands his subject and carries out is work. A good teacher has to possess not only a large measure of pure and applied knowledge and energy but also a taste for teaching.

A teacher who is thoroughly familiar with his subject and the systematic handling of same and wko knows the peculiarities of his pupils can be sure that they will follow him attentively. One of the worst sins of a school is boredom.

The instruction of grown men requires particularly careful treatment and a sympathetic attitude. The teacher must not appear as a superior but rather as a friendly counsellor of his pupils. He must educate them by force of example.

The manner and matter of every instruction must be carefully prepared. The material is to be carefully chosen in accordance with the syllabus contained in the service regulations and in other sources and is to be prepared to suit the intelligence, the degree of education and the mode of expression of the pupils.

Specially careful preparation is required for all such matter as is to form a summary of the result of the instruction which has gone before, whether the teacher causes verbatim copies to be made or whether he hands the pupils a printed copy. All writing which has to be done in connection with the business side of the teaching must be carried out either before or after the class.

Drawings and matters written up on the blackboard, which take some time to complete must be done before the class commences and experiments and practical demonstrations must be prepared out of service hours.

The regulations go on to read as follows :

The instruction is to be by demonstration, by means of the actual apparatus, models, drawings, plans and lantern slides; words are to be written

(1) This service order is to be found in the book: *Die Personalausbildung bei der Deutschen Reichsbahn* (Training of the staff on the Deutsche Reichsbahn), p. 168, and pp. 613 to 684.

down on the blackboard and the apparatus should be worked in front of the whole class. The demonstration is to be reinforced by the juxtaposition of opposites; comparisons are to be set up between the right and the wrong way, between the new and the old.

The subject matter is to be sub-divided and treated by sections. The teacher is to emphasise the sub-division either by drawing attention verbally or by writing up the headings on the blackboard.

The speed of teaching depends on the rate at which the pupils grasp the subject.

A good help to the memory is to give out and have copied down brief headings and sequences of ideas. This can however only be done to a small extent on account of the limited time available. The pupils are not required to copy out anything else in order not to distract their attention.

The pupils are to be handed concise printed texts to enable them to revise the subject matter at home. These text books are supplied for all subjects in accordance with the regulations by an organization of the Reichsbahn (Verkehrswissenschaftliche Lehrmittelgesellschaft) in Berlin which exists for the provision of school books, teaching apparatus, etc. The parts on permanent way, locomotives, locomotive running, workshop practice, political economy and management have already been published. Where printed books are not available, short extracts done in manifold are handed to the pupil. Is is expected that the lecture shall grip the audience and convince it. The lecturer shall utilize his own experiences without going into too much detail. He shall speak extempore as much as possible and not read from notes or from a book.

The principal points of the lecture must be emphasized by concise statements.

For pupils who are more or less unused to study, the class should not last longer than 20 minutes. The value of a lecture is greatly increased if followed by a short discussion. By this means the teacher can make sure that he has been understood and the pupil has an opportunity to obtain an explanation on points which are doubtful to him.

During the discussion the pupils are encouraged to discuss the subjects among themselves. The teacher shall briefly recapitulate the views expressed by the pupils and give his opinion on them.

Another method of giving service instructions is by a discussion. It consists of an interchange of ideas between the teacher and the scholars and is run on the lines of an instructive conversation in ordinary life. Arising out of the experiences and views of the pupils, a new point of view is developed by general discussion. A very necessary supplement to the class instruction are the exercices. By means of exercices the knowledge is strengthened and by practical examples the pupils gain a readier understanding and greater interest in the work. As exercices may be mentioned regular repetitions with discussions and homework. For the older scholars it is particularly advisable to arrange for exercises in the subjects by working out cases which, as far as possible, are chosen from actual practice.

In place of experiments in the classroom the actual processes in the shops or in running work are shown and explained. The transition stage from school to career consists in the classes in which the pupils themselves carry out the exercises.

§ 6. — **The service schools for beginners.**

This is to supplement the practical training of the beginners by teaching and to give them the necessary special knowledge to enable them to carry out their duties in a proper manner. For this purpose the beginners are instructed regarding the general groundwork of railway service and are introduced to the service regulations which concern them.

The beginners are to be given a general idea of the objects of the Reichsbahn and are to be given an understanding of the necessity of co-operation between the individual branches of the service in order to induce them to think and act in a business-like way. When introducing the service regulations the beginners are to be led to enquire into the spirit of the regulations and thus to recognize the inner reasons for these regulations in accordance with which they have to carry out their work. The instruction is to impress on them a sense of orderliness, readiness, willingness and the need for carrying out their duties in an exemplary manner.

The instruction must not be overloaded with matter which is beyond the scope of the future activities of the beginner.

Education in subjects of general knowledge does not form part of the objects of the school for beginners. Only in exceptional circumstances and for urgent reasons in connection with the service can supplementary instruction be permitted in the discretion of the Reichsbahn Management. This would only arise when under special local conditions the beginner is unable to obtain the necessary education in such subjects as are required of him for the proper performance of his duties, and which really belong to the general education which he should be able to receive at the primary school.

The following will take part in the school for beginners :

a) The beginners who are taking up clerical duties (Beamte) and who, having been admitted to the lowest position, are occupied in performing the prescribed preparatory service;

b) Employees who already hold positions as officials, and who, by order of or with permission from, the management are passing on to another branch of the service, for which they are not yet trained.

Officials, who on account of the particular work which they have to do, require to take a course of lectures at the school for beginners with reference to certain particular subjects, may be detailed to take part in certain classes of the school for beginners. In addition men, who are not under any obligation to attend the beginners' school, may be admitted to the whole of the classes or to classes dealing with particular subjects by permission of the Management.

The beginners are divided up according to their future functions for purposes of instruction in the school into a number of groups corresponding to the starting point of each career.

The instruction in the beginners' school is carried out on exactly the same lines as in an ordinary school. In dealing with service regulations the relationship and sequence of individual service operation (or procedure) are kept in the foreground. The teachers satisfy themselves by verbal questions, by repetition and by written exercises whether the pupils have properly followed the instruction.

Instruction is supplemented by practical exercises and inspections. Special

practising rooms are recommended for use in connection with the instruction for practical training (engine footplate, signals and points, model office, etc.)

Not more than 30 beginners should in general attend any one class. For demonstrations and practice work these are divided into groups.

Instruction is, as a rule, given by Reichsbahn officials possessing sufficient experience in the service; they are appointed by the Management.

Success depends primarily on the choice of suitable teachers. This must therefore be carried out with great care; such teachers must remain continually in touch with the actual practical service work. It is recommended that officials who have already shown merit in connection with service lectures should be employed by preference.

Discussions among the teachers for the purpose of exchanging their teaching experience, take place as required.

As far as possible the classes are held in the forenoon and last a full hour. The number of classes must not exceed five full hours in a day. Including inspections and practical demonstrations the number of hours may however be increased to 7.

In fixing the hours of classes consideration is given to the train service as it affects beginners coming from a distance. The class rooms must meet normal school requirements both as regards health and good taste in decoration.

Accessories employed for teaching in the beginner's school are :

a) Service regulations,

b) Elementary primers,

c) Memoranda and instruction leaflets,

d) Pictures and models,

e) Lantern slides and cinematograph films,

f) Full size dummy apparatus for practising upon.

The items *a* and *b* may be handed to the pupils against payment of the cost. The necessary service instructions, forms and the like, which are required for the use of the beginners during class hours must be available in sufficient numbers. It is a matter of principle that all service beginners should have an opportunity to participate in the classes of the beginners' school; exceptions can only be permitted by the Management.

The pupils must attend classes regularly and may not be removed without permission from the superintending office. Attendance at the school is controlled by means of simple registers. If a pupil is prevented temporarily from attending he must state reasons for absence to the teacher or director of the school. Leave of absence from classes comes under the same regulations as for any other kind of service leave. General supervision of instruction for service beginners is undertaken by the Reichsbahn Management and the persons conducting the different courses are appointed by the Management. Courses which are arranged to take place at a section office or at an important service station, are conducted by the Head of the section or his deputy.

The teachers make constant reports regarding the course of instruction and the subjects dealt with in every class. Examinations are not held at the end of courses, but report is made in the personal records of the beginner regarding his attendance at the school and he is given a certificate.

Applications for employment, appointments or promotions are not influenced

by attendance at the service school for beginners.

The works schools (apprentice schools) are considered as part of the service schools for beginners. These works schools are considered later on in conjunction with the practical training of apprentices.

§ 7. — **Schools of management.**

This is the higher stage of the school for beginners. Its object is to prepare beginners of the upper middle class service for duties in the managing departments or as heads of important service posts.

Attendance at the beginners' school precedes attendance at the school of management. The school of management is intended to enlarge the knowledge gained in the beginners' school and to increase the pupils' understanding of the general objects of the Reichsbahn and of the co-operation between separate branches of the service; it is intended to widen the horizon of the pupils and to bring home to them the importance of economic questions.

The school is to lead the pupils to study on their own account and must make them familiar with the appropriate literature.

The following are obliged to attend instruction in the school of management:

a) Reichsbahn civilian supernumeraries and aspirants,

b) Actual beginners of the upper middle class of service for civil, mechanical and electrical engineering, surveying.

Instruction is optional for :

a) The promotion officials (Aufstiegsbeamten) who are admitted to the upper middle class non-technical service.

b) The promotion officials admitted to the career of the upper middle class civil, mechanical and electrical engineering and surveying services.

It is left to the Reichsbahn directorates to decide whether officials coming from the higher public schools and who are being trained, are to attend the school of management for those subjects which are of importance for their particular training.

Officials who, in consequence of their occupation, need to hear lectures at the school of management on certain particular subjects, may be invited to take part in certain classes as « guest students ».

The regular service beginners attend the school of management in the second half of their training period, the promotion officials (Aufstiegsbeamten), on the other hand, do so during their preparatory occupation.

The students of the school of management are divided up for purposes of instruction into the following groups according to the starting point of their careers :

1. Senior clerks,
2. Senior technical clerks :
   a) Civil engineering;
   b) Mechanical engineering.
3. Senior clerks, survey department.

The general scheme of the school of management covers the following sections :

I. General management.
II. Finance.
III. Railway operating service.
IV. Traffic service.
V. Technical installations and arrangements (engineering).
VI. Foreign languages.

The courses made up of the different subjects differ in respect to the foregoing groups only as regards sections

IV and V. All students follow in common the general management, finance and railway operation courses.

A school of management is set up only at places where there is a directorate; opportunity must be given for attendance at some time every year. It is left to the directorate to arrange for the classes to be held continuously or only on certain days. The Reichsbahn Management compiles every year a timetable of the courses to be arranged at its own particular location. If it happens that for certain subjects the participating groups are too small the directorate arranges with other directorates, in so far as similar conditions and arrangments obtain, for the joint holding of these courses.

The classes of the school of management are to be held as far as possible during the periods when the men are least busy with service duties. Classes are to be held as far as possible in the forenoon. For continuous classes not more than five full hours a day and for the rest, not more than four full hours are to be taken. The hours of instruction per day may be increased to seven if inspection and practice work is included.

The form of instruction comprises a lecture followed by a short discussion.

The lectures may be supplemented by practical demonstrations, and inspections of installations of the railway and of private works are to be undertaken.

The instruction at the school of management is given by Reichsbahn officials in addition to their ordinary duties.

The teachers are selected from suitable officials in the directorate and in the sections; the special reporters (Fachdezernenten) of the directorate concerned are preferred.

The regulations for the beginner's school as regards class rooms and accessories hold equally for the school of management.

Regarding the equipment of the library for the directorate, consideration has to be given to the fact that suitable books can be lent out to the students of the school of management for purposes of private study.

The officials who attend the school of management either obligatorily or at their request must attend regularly and may not absent themselves without permission of the directorate. For this purpose a register of attendance is kept.

Should a student be temporarily prevented from attending he must without delay state the reason in writing to the head of the school.

The directorate exercises general supervision over the school of management. The reporter (Dezernent) concerned with teaching and education is appointed as actual head of the school.

Each participating group elects a deputy who represents the students of his group and who co-operates in looking after the attendance. When required, conferences may be held between the director of the school, the teachers and the group deputies.

Leaving examinations are not held. Their attendance at the school is reported on in the individual records of the students. It is necessary on principle that attendance at a school of management precedes the examination for senior clerk; exceptions to this rule can only be made by permission of the Reichsbahn Management. Attendance at the school of management does not count as regards appointment nor promotion.

§ 8. — **Service lectures.**

Lectures are divided into discourses on particular subjects and discussions on service matters.

The lectures on special subjects are intended to further the education of officials and to contribute towards increasing their efficiency. The task of this type of instruction is therefore to improve the knowledge of existing regulations and to make known new rules and arrangements.

At the same time an appreciation of the activities of other branches of the service is to be promoted. The object of the discussions on service matters is to instruct the officials regarding local events and arrangements, in order to ensure smooth working of local services.

With the lectures on particular subjects definite instruction is presented in a connected form; in the discussions on service matters, current events in connection with the service are brought forward in a more or less disconnected manner.

The lectures on special subjects cover the whole range of technical and non-technical services.

The lectures are divided up as follows :

I. Classes under a fixed time-table for officials coming from posts at a distance.

II. Lectures to be given if required :

a) For officials of the directorate offices, sections (inspectorates) and repair workshops.

b) For the heads of large railway stations, of important despatch departments, permanent way sections and operating centres.

III. Where required for individual groups of officials, special lectures or special courses to be arranged.

IV. Lectures on scientific subjects connected with railway work which the Reichsbahn works supervisors and assessors in course of training are obliged to attend.

All officials without respect for their age are obliged to attend the course of instruction arranged for them. In addition beginners and all other employees, whose instruction is necessary for service reasons are included in this training, for example, workers who are deputizing or helping the service officials.

The same rules regarding leave of absence from participation in the courses apply as for general service leave.

Officials are grouped as far as possible in such a fashion that each group receives instruction only in the subjects which are necessary for their particular service.

Systematic instruction for officials coming from distant posts shall, generally speaking, be kept separate in the case of :

1. Officials in the operating and traffic departments (train staff, station and despatch services, loading of goods service);

2. Officials of the permanent way and maintenance services, in the signalling and telegraph departments;

3. Officials of the locomotive running service (engine drivers, rail motor car drivers, rolling stock service and service on machinery and electrical installations);

4. Officials in the workshops services;

5. Officials of the water transport service.

When there is a sufficiently large number of officials at a particular ser-

vice post, sub-groups are formed, for instance men of the railway platform staff, pointsmen and signalmen, shunters and employees in the stores department, may each be formed into a separate group.

Participation in the classes does not confer any right to applicants for appointment or promotion.

The extent of the instruction which any particular official is to receive in the course of a year depends on the exigencies of the service.

For officials from distant posts classes must be arranged so that in the course of a year they shall have at least 12 times or from 2 to 4 times several consecutive hours instruction.

Discussions on service matters may be counted in. It is recommended that classes should be arranged during the hours when the traffic is lightest.

In addition to the classes according to time table, special lectures or courses can be arranged for individual groups of officials, when it is desired to instruct these without delay regarding important new regulations or technical innovations.

The number of participants at one particular class depends on the space available in the class-room but shall not exceed 40. Instruction on one particular subject must generally be repeated several times in order that all the men without exception can have an opportunity to be present.

Class work counts as service and is carried on as far as possible during working hours.

For groups of officials whose work is governed by the service regulations, the instruction is worked in so as to agree as far as possible with the divisions of working time. The time spent on class work includes travelling time and is to be calculated in accordance with the working hours fixed by service regulations.

The hours of the classes shall as far as possible not be held late at night nor just at the end of the ordinary working hours.

In arranging the time table of the courses, consideration shall be given to the hours of the trains affecting the students coming from a distance.

Classes for officials from distant service posts are held at the place where the number of available officials belonging to the same or a closely related branch of the service permits the formation of a group for instruction. Such independent locations for classes can in general be arranged at important railway stations and regulating stations, at repair shops and shops of the running department.

Officials belonging to minor service posts are allotted to a neighbouring group or are brought together for instruction. In special circumstances, suitable officials may be detailed to give the instruction at individual service posts.

§ 9. — **Subject matter, form of instruction and teaching staff in the service lectures.**

The subject matter for the systematic instruction at the distant service posts is decided upon for about 3 months in advance by the section offices according to the requirements of their particular section or in accordance with proposals submitted by the service posts themselves.

The subject matter is decided upon according to the particular requirements of practical work. Hence, service regulations and parts relating to the parti-

cular duties of the students are dealt with first, and the respective technical arrangements are explained at the same time.

As regards the operating department special emphasis is laid on the regulations which are important in respect to safety and reliability and on the method of dealing with irregularities. Included in the instruction regarding safety of operation, the rules on the prevention of accidents and against the misuse of alcohol have to be taught. A further guide for the choice of subjects may be found in the syllabus on the service school for beginners.

Occasionally the rights and duties of officials and workmen and welfare arrangements are discussed.

In the case of lectures for office staff and heads of important service posts the subject matter generally consists of the treatment of new regulations and new arrangements. For the men of the office staff provision has to be made in addition for instruction on commercial procedure as may be required.

The principal lines regarding the type and form of instruction laid down for the school for beginners hold equally for the service lectures. Reading out of regulations and instructions without a thorough discussion is of no value. The teaching staff must make their discourse interesting by quoting examples and must endeavour to secure the attention of their audience by a vivid presentation of the subject. The object of the instruction is to make the participants familiar with every detail of their service; hence in addition to explaining the meaning and object of a regulation, the reason for it should be made clear. Technical arrangements should, wherever possible, be explained at the installation itself, in case models and pictures are not sufficiently explanatory. In this case, likewise, the teacher must satisfy himself by questions as to whether his explanations have been properly understood and whether his students have properly mastered the subject of the lecture. It is therefore necessary to give the students an opportunity for discussion at every lecture.

The choice and training of the teachers for the lecture classes is of the highest importance as the success of the teaching depends principally on their ability. The teaching staff must, in addition to having a good general education, possess a taste and talent for teaching and at the same time have the necessary detailed knowledge of the subject and as far as possible have enjoyed special experience in the course of a fairly long period of service.

The head of a service post is the most suitable man to be the teacher at his own post, because he will know best what are the needs of his subordinates and can help them by suitable instruction. Where the head of the service post is unable to undertake the instruction, special local and travelling teachers are detailed. The travelling teachers are appointed by the Reichsbahn Management on the recommendation of the divisions for one or more districts. As far as possible the local and travelling teachers must be excused from other service, but care must be taken that they keep in touch with the practical work and are fully informed regarding new regulations and arrangements. It is useful to gather together from time to time the teaching staff of an important district for purposes of holding discussions, at which in addition to lectures on particular subjects, special discourses are

given on the system of instruction and examples for practice in teaching are introduced.

The lectures on special subjects are given by selected officials (specialists), whose task can frequently be limited to preparing the heads of service posts and teaching officials for their instruction work.

The lectures for heads of important service posts are given by chiefs of divisions or their deputies, particularly if it is not a question of dealing with special subjects. The men chosen for giving lectures to the office staff are specially detailed in each case on account of the need for their having a special knowledge of the subject.

§ 10. — Educational appliances and classrooms.

Explanations made with the help of models and pictures are often a necessity for a better understanding of the subject. It is therefore necessary to pay attention to the collection of educational appliances. It is not necessary that every school should have a complete collection.

Under suitable distributing arrangements a single travelling collection especially in connection with travelling teachers and making use of instruction coaches, may be made to suffice for a large district.

The collections of educational appliances shall include in addition to models, samples and materials, cards and pictures, the necessary books, primers and service regulations required for the particular instruction. The teachers are regularly supplied with a teacher's journal dealing with matters concerning the railways.

When important lectures are given it is advisable to hand the students an extract or digest of the lecture in the form of a leaflet.

At all important instructional centres a special lecture room shall be supplied which under favourable circumstances may be used by several service centres in common.

The classroom is to be provided with the necessary apparatus and should where possible be arranged for using a magic lantern or cinema. At smaller service centres where a special classroom cannot be provided, care should be taken to see that the available room shall have sufficient seating accommodation and should be supplied with a blackboard.

In suitable cases an instruction coach shall be provided in connection with the lectures.

§ 11. — Conduct and supervision of service lectures.

The supervision is carried out by the Reichsbahn directorate under which the particular officials who are to be taught are employed. In the case of instruction at the directorate and for all special lectures in which officials of several districts participate, the special reporter for the instruction work makes the necessary arrangements in consultation with the official dealing with the general subjects.

The classes to be given at the distant service posts are controlled by the division in question, which hands over for this purpose to one of its officials the whole of the work connected with the instruction.

It is only when the classes are planned with the greatest care and the class

work is continually supervised that the progress of the servants of the railway as regards their teaching can be assured. Heads of divisions are therefore obliged from time to time to be present at the classes and to determine, when examining the manner in which duties at any particular service post are carried out, whether the regulations regarding the system of service lectures are being adhered to.

Instructions are given regarding time and subject of the lectures as also regarding participation in the classes.

§ 12. — **Discussions on service matters and special courses of instruction.**

The foregoing arrangements for special lectures apply equally as regards the lines on which they are worked, to service discussions.

In the service discussions, local service matters, important new arrangements and special incidents, changes in the time-table and in the tariffs, which take place at the commencement of the winter service or measures to be adopted in case of traffic congestion, reconstruction of the permanent way, other changes affecting the service post, as also defects in carrying out the work, are all dealt with.

Service discussions take place several times a year according to requirements, and always at the service centre itself and are conducted by the head of the post or his deputy. The participants are the same as for the special lectures, although in this case the formation of groups is less important and is left to the discretion of the head of the service post. The service discussions count as working time.

A note made regarding the date, the subject and the participating group of officials suffices as proof that the discussions have been held.

Service lectures include among the classes to be held according to requirements, discourses suitable for office men of the directorates, divisions and repair shops, also for the heads of large railway stations, of important despatching departments, permanent way sections and of traffic departments works.

The scientific lectures in connection with railway matters dealing with electrical engineering, mechanics, operation and traffic, finance, etc., are subject to special arrangements.

These lectures are attended especially by higher technical and administrative officials who are in course of receiving their training. The lectures which consist of one or two 2-hour classes per week generally extend over a whole term. In the last few years, where a management college was in existence at the particular place, it was generally arranged for the latter to include such lecture courses in their syllabus.

When required for individual groups of officials special lectures or courses can be arranged. These find a special application in sudden or periodic exigencies of the service, as for example, the instruction of officials of a district where new sections are about to be electrified, in anticipation of heavy autumnal traffic, under the need for a speeding up of the circulation of rolling stock, for the education of the personnel to meet new traffic requirements, the introduction of new service regulations, the meeting of newly arisen competition and for considering questions of obtaining new traffic, the introduction of new methods of operation in the workshops, the introduction of new types of locomotives, for the purpose of

introducing travelling teachers to their sphere of activity, etc...

As complemental courses may be mentioned systematic instruction which is intended to deal in greater detail with subjects which are already provided for in the ordinary syllabus, for example, when it is a question of dealing in a particular district with specially difficult questions concerning the permanent way, signalling or operation. The special and complemental courses last as a rule only from 1 to 3 days; exceptionally they may be continued for several weeks, as has happened for example for freight controllers and permanent way officials at the central school at Brandenburg West. At Berlin-Tempelhof an extended course was set up for drivers of rail motor cars in order to familiarize the men in view of the introduction of electric operation on the Berlin Metropolitan Railway (City and Circle) and to instruct them in the details of the new coaches and the method of driving them. Four to five hours instruction are given daily in addition to which practical exercises are provided for. Such courses are most suitably arranged for at the central schools where they have great experience and are well equipped with demonstration apparatus.

The convening of officials at one place leads in addition to a particularly active interchange of experiences gained in the service. Further, the management which has to pay travelling allowances is able to economize in this direction by providing sleeping accommodation in the establishment.

§ 13. — The central schools of the Reichsbahn.

Here it is not a question of a special type of school in the sense of the service school for beginners or the management school, but rather of the provision, in the groups of directorates on a larger scale than is possible at individual centres, of a specially built institution containing classrooms, practice apparatus, collections of models, etc., together with arrangements for housing and feeding from 50 to 100 persons.

Such a central school is naturally very suitable to be used for several other cognate purposes, such as for instance, the combined instruction of service beginners from several groups of directorates. By this means, instruction in individual districts by means of their own beginners' schools for particular groups of officials can be saved and at the same time a highly economic utilization of the teaching staff and instructional arrangements can be achieved.

It is an important characteristic that the central schools are provided with dummy apparatus. Thus it is possible to teach the beginners of a particular group of officials in a specially efficient manner by means of the dummy apparatus.

Under these conditions the time for training can be materially reduced. In this lies the great economic importance of systematic instruction arranged in the way described.

These facts have already been shown to be of practical importance on the Reichsbahn.

We transcribe here in full a portion of the official instructions concerned.

Service beginners training as operating assistants and assistants, who have attended the central school at Hanau, may have their period for training as laid down for their career reduced under approval, namely for beginners as operating assistants, a reduction of from

10 to 8 months and for assistants from 12 to 10 months.

In so far as the training period laid down by the Federal Council in their efficiency regulations, is not fully completed in consequence of this shortening of the period, we authorize the adoption of this measure in accordance with section A, clause 7 of these regulations.

If there arises any need for the training of beginners as station officials, guards, shunters and pointsmen, these employees are to have instruction at the central school and as a result the period of their practical preparatory work is to be shortened and the results observed are to be reported on at the proper time.

In order that the instruction at the central school should result in every case in a shortening of the practical preparatory work, we request in conjunction with the Reichsbahn directorates, to arrange that the beginners shall attend the schools sufficiently early so that they should not miss any material proportion of the classes.

Another great undertaking, the Berlin Tramway Company, has made such good use of a similar establishment that the period of training could in part be reduced by more than 40 %.

The Reichsbahn has so far installed three central schools at Hanau, near Frankfort-Main, at Freimann, near Munich and at Brandenburg-West, near Berlin.

These are provided with lecture rooms, dormitories and mess rooms, dummy apparatus, models and collections. Thus for example at Brandenburg-West a large room is provided for the exhibition of teaching appliances concerning the permanent way (see fig. 11); further the system of signalling, current technics and safety arrangements, central signal and point-interlocking frame for teaching beginners, with an extensive installation out of doors (this is noticeable in the ground plan, fig. 8). A further room is available close to the interlocking frame for 40 pupils and a large hall with educational appliances and other apparatus concerning traffic, engine running and workshop services.

The usefulness of the central schools is already considerable, but it will increase substantially, as soon as officials in larger numbers are required for training and the saving in the training period and hence in the salaries and wages, becomes noticeable to a greater extent.

§ 14. — The training of apprentices and probationers.

Young people are trained at the railway workshops as apprentices to various handicrafts. Of the 3 313 apprentices of the year 1927, 2 889 were fitters, 182 fitters and turners, 132 boilermakers, 28 carpenters. The remaining 82 apprentices were distributed among various handicrafts. The proportions do not vary much from year to year and one can count on 87.5 % for fitters, 4 % as boilermakers and the remaining 8.5 % are divided up among other handicrafts.

The youths are given 4 years' training, of which the fitters apprentices have three years, tuition under a teacher at a special apprentice workshop. The work to be done is chosen both from the educational and economic point of view.

In addition there is a theoretical course at the Reichsbahn works-school. This course has for its object the special training of the apprentice for his particular trade and at the same time to

Fig. 2. — Central school at Hanau.

Fig. 3. — Dormitory for officials at the Central school at Hanau.

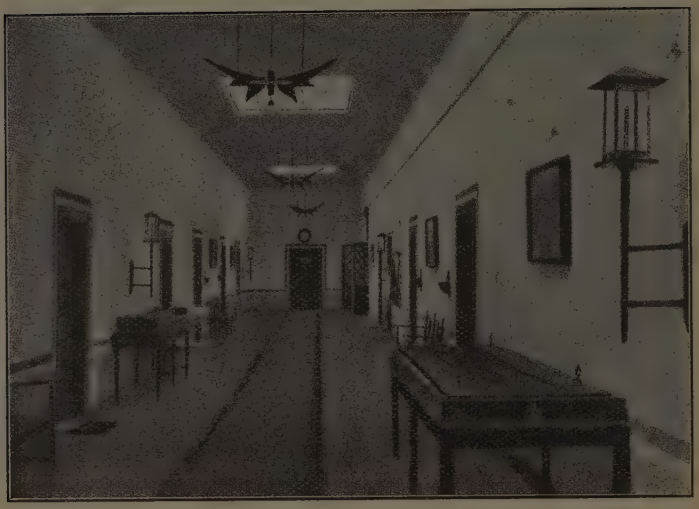

Fig. 4. – Corridor at Central school at Munich (Freimann).

Fig. 5. — Corner of recreation room, Central school at Munich (Freimann).

Fig. 6. — Second recreation room at Central school, Munich (Freimann).

Fig. 7. — View of the school and dormitory building of the Central school, Brandenburg-West.

make a good citizen and a worthy man of him.

The apprentices at the railway repair works are obliged to attend the works-school belonging to the railway, during the whole of their apprenticeship, and to take all the subjects comprised in the syllabus. If there is no works-school attached to the repair shops, the apprentices must attend the public profes-

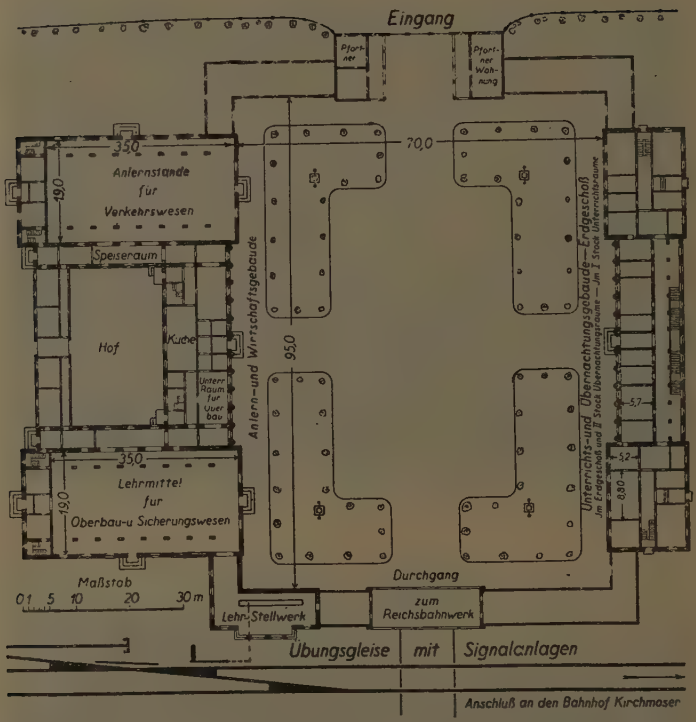

Fig. 8. — Ground plan of the two main buildings of the Central School at Brandenburg-West with dormitories, collections of demonstration apparatus and dummy apparatus.

Explanation of German terms : Anlernstände für Verkehrswesen = Dummy apparatus for traffic work. — Anlern- und Wirtschaftsgebäude = Building containing instruction rooms and offices. — Anschluss an den Bahnhof Kirchmoser = Track leading to Kirchmoser station. — Durchgang zum Reichsbahnwerk = Passage to railway workshop. — Eingang = Entrance. — Hof = Courtyard. — Küche = Kitchen. — Lehrmittel für Oberbau- und Sicherungswesen = Instructional apparatus for permanent way and safety devices. — Lehrstellwerk = Interlocking frame for learners. — Pförtner = Gatekeeper. — Pförtner Wohnung = Gatekeeper's living rooms. — Speiseraum = Messroom. — Übungsgleise mit Signalanlagen = Tracks and signals for exercises. — Unterraum für Oberbau = Basement, for permanent way work. — Unterrichts- und Übernachtungsgebäude-Erdgeschoss etc. = Building for classrooms and dormitories-basement. (Dormitories in basement and second floor. Class-rooms on first floor.)

sional school at the place where they are quartered and in addition they have to take the supplementary classes provided by the works management. No fees are required for the education provided by the railway.

As a rule there are 4 classes provided, corresponding to the 4 years of apprenticeship. The course of instruction covers technical subjects and duties of citizenship together with composition and ordinary arithmetical calculation, the

Fig. 9. — Dormitory in building containing classrooms and dormitories, Central school at Brandenburg-West.

Fig. 10. — Mess room in the building for instruction and offices, Central school at Brandenburg-West.

Fig. 11. — Hall in building containing instruction rooms and offices, in Central school at Brandenburg-West (permanent way work).

study of building materials, labour conditions, mechanics, electrical engineering, machine drawing, physical exercises and practical work. In the two first years, ten hours a week are allotted for classes and the two last years, 9 hours a week, in both cases for 40 weeks in the year.

The school is directed by the manager of the works or by a deputy appointed by him. Where possible the school is managed by an official belonging to the division. This official is at the same time made responsible for all matters connected with the apprentices. He is responsible for the regular routine of management and has himself to teach from 10 to 16 hours every week.

For purposes of instruction, professional-school teachers and elementary-school teachers who have passed the government tests and possessing long experience in technical school service come under consideration and more especially railway officials, who in addition to a good general education are thoroughly acquainted with the special subjects which they have to teach and have had long and varied practical experience. In choosing these men, preference must be given to those who have a talent and the taste for teaching. Moreover they should be suitable as regards their conduct both in their official dealings as also in their private mode of life, in order to provide the pupils with an example of steady and conscientious attention to duty, for example is the best means of education.

Where there is sufficient work to occupy them the instruction is to be given by officials from the divisional office.

At suitable workshops, some of the youths, who are taking up a senior or middle class technical carreer, are admitted to the practical instruction and partly also to the works-school classes. Their training is carried out in a similar fashion to that of the apprentices.

§ 15. — **Instruction coaches, dummy apparatus, and interlocking frames for learners.**

Instruction coaches serve principally as classrooms in connection with apparatus and collections of model gear and are used principally at railway stations where there is no suitable class room, particularly for demonstrating apparatus and showing lantern slides. In addition the coaches are used for instructing employees quickly in the innovations regarding methods of operation, of construction or organisation, particularly when the matter is particularly urgent and when lectures with photographs and lantern slides are necessary for the good comprehension of the matter. Time and trouble is saved to a considerable degree by demonstrations in such a coach which has been fitted up once and for all with the necessary apparatus. At important railway centres the coaches can be taken out into the neighbourhood of the groups of workers and officials who are frequently stationed all over the country-side, so that they do not lose much time in getting to their classes and that advantage can be taken of the slack periods of operation to work in the instructions. External view and plan of the coach are shown in figures 12 to 15.

Among these the special coach for psycho-technical purposes is noticeable.

In a number of cases, the period of training of an official may be shortened or at least may be rendered more effective by allowing the candidate to train on special dummy gear, thus acquiring a facility in the manipulation of the apparatus, which he would be unable to achieve under ordinary routine conditions. Thus beginners at the Central School of Brandenburg-West, who are taking up traffic work, are introduced to every process which occurs in practical working at a number of places or stands which are an exact replica of the actual apparatus. Further, nearly every one of the important Reichsbahn directorates has at its disposal an interlocking frame and signal installation for instructional purposes. Figures 16 and 17 show these as installed at Stettin and Munich (Freimann).

Trials can be made with artificial failures and practice can be given in removing the causes of the irregularities.

In figure 18 is shown a teaching model for booking clerks at the Central School, Hanau.

There is also a dummy gear for rail motor coach drivers.

Each of the central schools has at its disposal good models, maps, posters, arrangements for lantern slides, etc. The effectiveness of the instruction is increased by means of handbooks (manuals), which are published by a publishing company created for the purpose and known as the Verkehrswissenschaftliche Lehrmittelgesellschaft (Publishing company for the science of transportation). This undertaking which is worked on ordinary commercial lines is governed by the director of the schooling and educational system of the Reichsbahn. This director edits in addition and for the same purposes a journal for schooling and education called « *Der Eisenbahnfachmann* » (publisher H. S.

Fig. 12. — Exterior view of instruction coach of the *Eastern* Reichsbahn directorate.

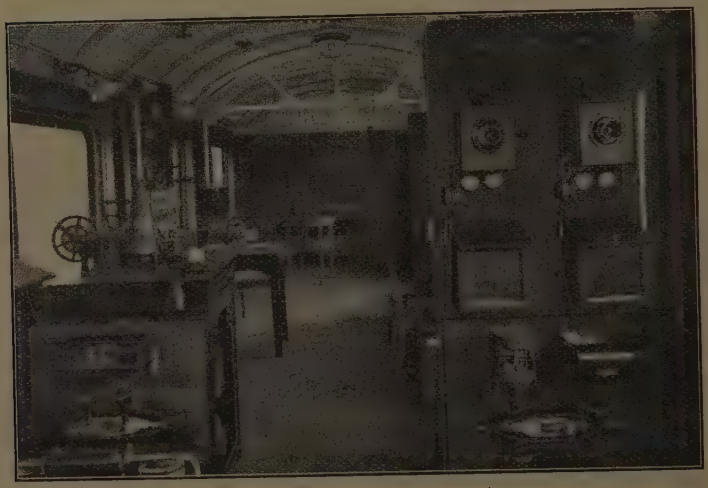

Fig. 13. — Interior view of instruction coach for telegraphy and telephony of the *Eastern* Reichsbahn directorate.

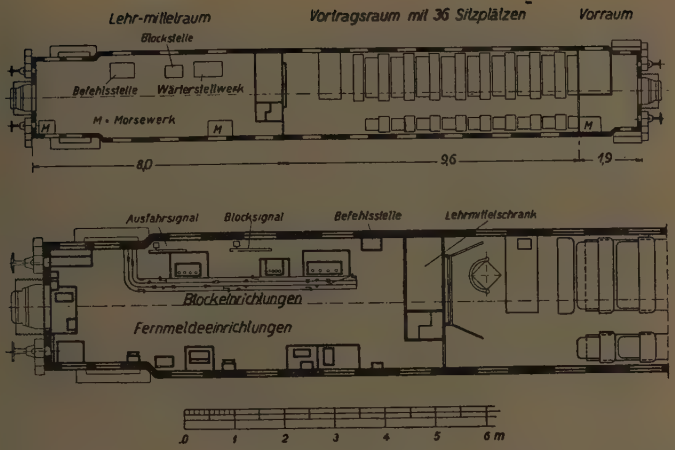

Fig. 14. — Diagram of instruction coach for telegraphy and telephony of the Reichsbahn directorate at Altona.

Explanation of German terms : Ausfahrsignal = Starting signal. — Befehlstelle = Control post. — Blockeinrichtungen = Block system installation. — Blocksignal = Block signal. — Blockstelle = Block post. — Fernmeldeeinrichtungen = Telegraph and telephone installations. — Lehr-mittelraum = Room with apparatus. — Lehrmittelschrank = Apparatus cupboard. — Morsewerk = Morse instruments. — Vorraum = Vestibule. — Vortrags- — raum etc. = Classroom to seat 36. — Wärterstellwerk = Attendant's locking frame.

Hermann & Co., Berlin). Its object is principally to promote further independent study by good articles and by exposition of examination questions. Both the journal and the books are distributed abroad.

The three psycho-technical testing laboratories of the Reichsbahn at Berlin-Grünewald, Munich and Dresden work in close co-operation with the educational system. The ground plan of the institute at Berlin is seen in figures 19 and 20.

Since 1921 more than 70 000 persons have been examined at this institute, for suitability. The results are very favourable.

Apart from examination of new candidates the institutes concern themselves with teaching manual operations on a psycho-technical basis.

§ 16. — The voluntary educational system.

The Reichsbahn considers it of importance to encourage to a far reaching extent the efforts of its employees to educate themselves. As a result the voluntary system of education has reached a more favourable development with the Reichsbahn than with any other German organization.

The result, hard to obtain when looked at from the political point of view, is that all the railwaymen associations (syndicates), no matter of what political tendency and in spite of all the great

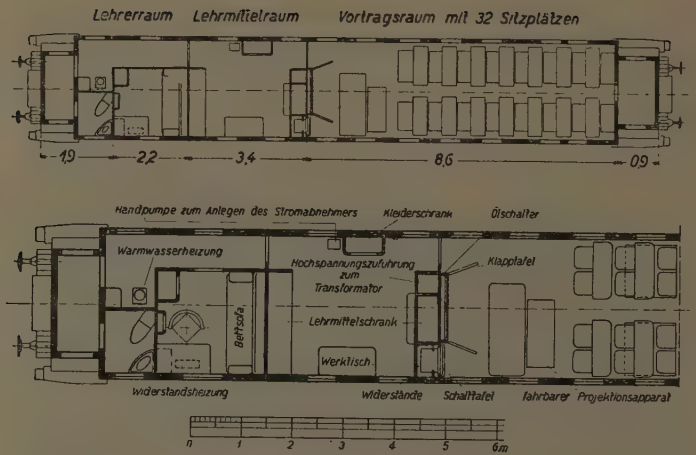

Fig. 15. — Diagram of instruction coach of the Reichsbahn directorate at Breslau.

Explanation of German terms : Bettsofa = Sofa bed. — Fahrbarer Projektionsapparat = Portable projector lantern. — Handpumpe zum Anlegen des Stromabnehmers = Hand pump for setting on the collector bow. — Hochspannungszuführung zum Transformator = High tension connection to transformer. — Klapptafel = Hinged table. — Kleiderschrank = Wardrobe. — Lehrerraum = Instructor's compartment. — Lehrmittelraum = Instruction room. — Lehrmittelschrank = Apparatus cupboard. — Ölschalter = Oilswitch. — Schalttafel = Switchboard. — Vortragsraum etc. = Classroom to seat 32. — Warmwasserheizung = Hot water heating. — Werktisch = Bench. — Widerstände = Resistances. — Widerstandsheizung = Electrical resistance heater.

differences and disputes existing between them, have united, in respect to education, to form the Association of Reichsbahn technical schools.

The Association has attained a successful development through its efforts to secure efficient teachers and a really good system of instruction and it now possesses branch schools in more than 40 towns. A contract has been made between the Reichsbahn and the Association, which refers principally to the use of classrooms, educational apparatus and within certain limits, free passes on the railway. During the time the contract is in force the Reichsbahn will support no other undertaking having the same objects in view. The schools of the Association form an invaluable supplement to the service instruction, particularly for the lower grades of officials.

In addition the Reichsbahn co-operates with the high schools of administrative science and has likewise made a contract with them. They provide, in academic form, lectures for those officials who wish to extend the field of their knowledge on a more scientific basis. These colleges are open to the officials of all administrations. The railwaymen form a separate group. Every year meetings lasting a week, for discussion of scientific matters in connection with railways, take place in Berlin and Munich; in these meetings lectures are given by well-known technical experts on matters connected with railways. Foreign railway officials, from Austria, Sweden,

Fig. 16. — Instructional interlocking frames at the Central school at Munich (Freimann).

Fig. 17. — Instructional locking frames at the Reichsbahn directorate at Stettin (transverse view.)

Fig. 18. — Teaching counter for booking clerks at the Central school, Hanau.

Denmark, Russia, Finland, Norway and Switzerland, among others, likewise take part in the meetings.

The Association of German engine drivers arranges every year at their rest house in Hanoversch-Münden continuation courses for their members. These courses are well attended and are provided for out of their own funds.

The learning of shorthand and the development training in this subject is supported by the Reichsbahn Shorthand Associations, possessing over 30 000 members. They also provide for the physical well-being of their members by means of railway gymnastics and sports clubs which are united in one great league.

The Reichsbahn in its capacity as the largest industrial and managerial corporation possessing such a far reaching system of education and training keeps in touch with the intellectual tendencies of the time, more especially as they are evinced at the universities and technical high schools. The opportunities for mutual support and the implanting of new ideas are very great, in view of the fact that, apart from purely abstract science, there are few directions in which the Reichsbahn is not interested both practically and industrially.

§ 17. — Cost of the official teaching.

At the present time the service beginners' schools cost annually in round figures 800 000 Rm., an amount which will increase at a moderate rate with a growing number of officials appointed. The expenses on the management school come to approximately 42 000 Rm. and

Fig. 19. — Section plan of basement and mezzanine of the Psychotechnical Institute, Berlin-Eichkamp.

Explanation of German terms: Ausstellungsraum = Room for exhibits. — Herren = W. C. — Kinoraum = Cinema room. — Kleiderablage = Dressing room. — Untersuchungsbeamte = Examining official. — Untersuchungsraum = Room for psycho-analytical examination. — Vortragsraum = Lecture room.

Fig. 20. — Section plan of the upper floor of the Psychotechnical Institute, Berlin-Eichkamp.

Explanation of German terms: Anmeldezimmer = Waitingroom. — Bote = Messenger. — Dezernent = Reporter. — Flur = Vestibule. — Garderobe = Cloakroom. — Geschäftszimmer = Office. — Sitzungszimmer = Board room. — Statistisches Büro = Statistics office. — Technisches Büro = Technical office. — Untersuchungsraum = Room for psycho-analytical examination. — Werkstatt = Workshop. — Wissenschaftlicher Hilfsarbeiter = Scientific assistant.

the largest outlay, namely for the system of service lectures comes to 5 million Rm. All this only amounts to 0.56 % of the salaries of officials for 1 year. The outlay for the works-schools runs to approximately 650 000 Rm. or 165.00 Rm. per pupil. The cost of teaching appliances, accommodation and interest on capital outlay are included. In spite of the fact that it provides for more than 700 000 officials and workmen, the grand total cost of education and training does not amount to 7 million Rm. and does not even reach the annual outlay on such matter of fact and inexpensive articles as for example cotton waste, to say nothing of lubricating oil and coal.

[621 .132.8]

REPORT No. 3

(All countries excluding America, the British Empire, China, Japan, Belgium, France, Italy, Portugal, Spain and their Colonies)

ON THE QUESTION OF LOCOMOTIVES OF NEW TYPES; IN PARTICULAR TURBINE LOCOMOTIVES AND INTERNAL COMBUSTION MOTOR LOCOMOTIVES (SUBJECT V FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

By Paul KOLLER,

Engineer, State Councillor and Assistant Director of the Czechoslovakian State Railways.

Figs. 1 to 8, pp. 1269 to 1291.

1. The type of locomotive evolved by Stephenson about the year 1830 has survived up to these days in all essentials without any great alteration, with only a few improvements of greater or less importance in details of construction or in its method of working.

Efforts have been made to alter the construction of some of its characteristic components on account of the trouble which they have given, this being especially the case as regards the firebox made of large flat copper plates with numerous stays. We will only mention one of these modifications, *viz.* the Brotan firebox which was widely used before and during the War in Central Europe, especially in Austria and Hungary. Of the Administrations belonging to the International Railway Congress Association it is mainly the Polish State and the Czechoslovakian State which at the present time possess a certain number of engines of this type.

A. — Partial modifications to the construction of locomotives.

The Brotan water tube firebox.

2. The construction of the Brotan water tube boiler is well-known. The side walls of the firebox are replaced by large water tubes. The upper end of these tubes are fixed in one or two drums communicating with the barrel. The lower ends are fastened into a hollow foundation ring. This is also connected with the barrel. In this way free circulation of the water in the firebox tubes is ensured. The barrel is of the orthodox type, excepting that the firebox tubeplate is circular like the smokebox tubeplate.

3. The Brotan boiler is well designed and steams freely on account of the water tube firebox; the steam produced, however, is wetter than in an ordinary boiler. The efficiency of the boiler is good and from tests carried out on the Polish State

(1) This question runs as follows : « Locomotives of new types; in particular, turbine locomotives and internal combustion motor locomotives. Construction, efficiency, use and repair. »

(2) Translated from the French.

Railways the consumption of fuel in a Brotan boiler is about 5 % less than in a boiler of orthodox type.

4. Compared with the ordinary firebox the junction between the foundation ring and the barrel is less rigid and contains a certain number of parts where the metal is affected by alternating stresses caused by expansion and by vibration, which causes fatigue of the material. The cracks which develop at these places make it necessary to replace the parts in question after a relatively short time. It is also difficult to keep the water tubes permanently tight in the steam drums. The defects are for the most part developed :

a) In the corners of the lower part of the firebox tubeplate;

b) Around the openings in the firebox tubeplate which are riveted to the steam drum;

c) In the water tubes;

d) On the circumference of the steam drum.

Leakage is apt to develop at the following points :

a) Rivets around the firebox tubeplate;

b) Rivets between the steam drum and the boiler barrel;

c) Where the water tubes enter the steam drum;

d) Connections between the foundation ring and the barrel.

The water tubes of the Brotan boiler require frequent scaling, especially where the feed water is not good, and this requires special scaling tools.

The Brotan boiler in view of these disadvantages has been abandoned in all the countries where it had been adopted. No new ones are being made, and on existing engines these boilers are being replaced by normal boilers during general repairs.

5. This example shows the great importance in a new type of boiler of carefully avoiding fatigue of the material. In this way failures in service and costly maintenance can be avoided. Troubles of this kind do not as a rule appear until after several years in service, a reason which fully explains the caution with which the railways adopt new forms of construction.

6. The Brotan boiler only represents a partial change from the orthodox type. In recent years attempts have been made to improve the locomotive as a whole by making far more drastic changes in its construction. We will review the present-day condition of these experiments in Central, Southern, and Eastern Europe.

B. — Locomotives of new types.

7. The efforts to produce a new type of locomotive are mainly based on the fact that the efficiency of present-day locomotives is low compared with stationary power plants. From the point of view of finance and political economy it is desirable to reduce as far as possible the cost of fuel which is about 10 % of the cost of railway operation. The over-all efficiency of a locomotive, that is the ratio of useful work done at the drawbar to the calorific energy of the fuel for the best locomotives working under the most advantageous conditions is at present about 8.5% at the most, *i. e.* 7 435 calories (30 500 B. T. U.) per effective drawbar horse power-hour. The efficiency of the older type of engines is considerably less, and moreover a locomotive is working for a great part of the time under less favourable conditions, so that on the average even this relatively low efficiency is far

from being obtained. In comparison with the modern steam power plants or with Diesel engines the efficiency of the present day steam locomotives, even under the most favourable conditions, is only about 1/3rd; one can thus easily understand the attempts to apply to the steam locomotive the principles and method of construction which have given good results in stationary practice.

8. Unfortunately these attempts meet with great difficulties since it is necessary to adapt them to the conditions which a locomotive has to fulfil as a means of transport. A locomotive has to draw a train of varying weight and composition over a road with various gradients and curves according to the country traversed, under varying atmospheric conditions and at speeds ranging from zero to the maximum speed for the engine in question.

For an engine which has to work under such varying conditions the driver should be able to modify the power and the ratio of the two factors which determine the power, *viz.* tractive effort and speed, without affecting the efficiency. Obviously it should be able, where possible, to work at full power, thus fully utilising the capital invested in the engine, and if necessary the engine should even be able to take an overload over a short period. The locomotive should also be reliable and be capable of running either backwards or forwards. Moreover it must conform to the maximum dimensions imposed by the loading gauge and by the length of turntables or traversers and by running shed and erecting shop doors. Its weight must not exceed the weight allowed by the permissible axle load or by the permissible weight per unit length of vehicle. Finally, it must be of robust and simple construction, must be easy to handle and the capital cost and maintenance cost must be low.

It is not sufficient to judge a locomotive from the point of view of fuel economy alone, as the fuel costs are not decisive. It is the total cost per unit of work done by any type of locomotive which must be considered.

9. The ordinary reciprocating locomotive, although not an absolutely ideal means of transport has been developed into a machine which meets the requirements of traffic operation not only in a general manner, but in all its details. The modern attempts to improve the efficiency of a locomotive are based, however, as we shall see, on very drastic alterations discarding even the essential features of the normal locomotive. This is where considerable difficulty is met as it is not sufficient that the new type of engine should have a higher efficiency, it is also necessary that it should be as good as the old type from the other points of view.

10. We may consider the over-all efficiency of a steam locomotive as being the product of three partial efficiencies, *viz.* the thermal efficiency of the boiler, the thermal efficiency of the engine, and the mechanical efficiency from the piston or turbine rotor to the drawbar. The thermal efficiency of the boiler may be defined as the ratio between the heat in the steam supplied to the cylinders and the calorific value of the fuel burnt. By the definition we consider the heat contained in the steam used by accessories as a loss from the boiler thus reducing its efficiency in proportion (about 3 % in present day locomotives). This may be partially offset by taking into account the heat supplied to the boiler in the feed water by means of an exhaust steam feed water heater, *i. e.* by calculating the heat

produced by the steam above the temperature of the water in the tender. The efficiency of a modern locomotive boiler calculated on this basis is about 75 % or in isolated cases may be as much as 85 %. Therefore the efficiency of a modern locomotive boiler is little less than the efficiency of stationary boilers. The thermal efficiency of the engine is a ratio between the work done on the piston and the heat energy in the steam supplied to the cylinders. This efficiency does not as a rule exceed 12 to 13 % in present day engines. The mechanical efficiency is a ratio between the work produced at the drawbar and the work done on the piston. In modern locomotives even in those with a large number of coupled wheels, the mechanical efficiency is very good being rarely less than 90 %. The thermal losses in a modern engine with feed water heater is therefore approximately as follows : Boiler losses are about 1/4, losses in the cylinders about 2/3rds and the losses in the mechanism about 1 %. The work developed at the drawbar is at most about 8.5 % of the total energy in the fuel. Excluding the mechanical efficiency which is quite good and of secondary importance, the total efficiency of the engine may be increased by either improving the efficiency of the boiler or of the engine. The thermal efficiency of an ideal engine working without loss is given in accordance with Carnot's principles by the ratio of the difference between the initial and final temperature divided by the initial temperature in degrees absolute. To improve this efficiency it is therefore necessary to increase the initial temperature and to diminish the final temperature as far as possible. As far as concerns the production of steam it is particularly important to reduce as far as possible the temperature of the products of combustion leaving the boiler. These may be utilised for two purposes :

a) To give additional heat to the feed water already heated by using exhaust steam;

b) To preheat the air for combustion.

In the case of the steam locomotives attempts have been made to increase the thermal efficiency by introducing a condenser, *i. e.* to lower the final temperature or to increase the pressure and superheated temperature of the steam, *i. e.* to increase the initial temperature. In internal combustion engines, especially of the Diesel type, the initial temperature of the gas is very much higher than that of the steam in the steam engine, the thermal efficiency being considerably higher. Another method, therefore, of improving the efficiency of a locomotive lies in the complete abandonment of steam and replacing it by another heat engine with a higher efficiency such as for example a Diesel engine.

11. It is mainly on the basis of the foregoing that new types of locomotives have been constructed. Efforts to introduce a condenser have led to reciprocating engines being replaced by the steam turbine, while the introduction of high steam pressures has led to the abandonment of a normal type of boiler and to the use of water tube boilers, and also to types of steam engines suitable for high pressure which differ from normal locomotive practice.

Finally the use of a Diesel engine has led to a still greater departure from the normal type of locomotive.

In view of the foregoing we may divide new types of locomotives into three principal categories :

I. Condensing turbine locomotives with the normal type of boiler.

II. High pressure locomotives with a new type of boiler working: *a*) with exhaust to atmosphere, *b*) with a condenser.

III. Diesel locomotives or locomotives with another type of high efficiency engine.

12. Of the Administrations belonging to the International Railway Congress Association included in the present report (other countries), it is mainly in Switzerland and Sweden that new types of locomotives have been built and tested, *viz.* the Ljungström turbine locomotive in Sweden and the Zoelly turbine locomotive in Switzerland, and finally the high pressure locomotive (60 at. = 850 lb. per sq. inch) built by the Swiss Locomotive Company at Winterthur. Moreover there is in service a small Diesel locomotive on the Danish State Railways, and also on some of the Swedish Railways. The Administrations and builders concerned have been kind enough to give us all the particulars we have asked for, and also they allowed us to make a personal examination of the new engines, for which we are very much obliged. In the other countries dealt with by this report, the locomotives of new type have not up to the present been constructed or used in traffic. On the other hand some railway administrations which are not members of the association have given particular attention to the question of new types of locomotives, as for example, the German State Railways (Reichsbahn) (1), the Russian Soviet Railways and the Austrian Railways.

It has appeared desirable to include these countries in the present report, although it has been necessary to use information taken from the technical press or supplied to the reporter by the builders. This report does not give a detail description of the locomotives mentioned, but confines itself to the principal features and to results obtained in tests. For fuller information we would refer the reader to the bibliography given at the end of this report.

I. — Condensing locomotives without any appreciable increase in pressure. Turbine locomotives with the normal type of boiler.

13. The results obtained in stationary practice have proved the advantage of condensation. On the other hand the fact that for many years this has not been applied to locomotives is due to the great difficulties of equipping a locomotive of limited dimensions and weight with the bulky parts required for condensation, and of maintaining these parts in good running order.

14. Low pressure steam occupies a considerable volume. The cylinders of condensing reciprocating engines should therefore have such dimensions that for present day powers of about 2 000 H. P. it will be very difficult to find room for them in the space available on a locomotive. This is the reason why it is almost essential to replace the reciprocating engine by a turbine if condensation is to be effected (1).

(1) At the time this report was written. — The German Government and the German State Railway Company (Deutsche Reichsbahn Gesellschaft) are now members of the International Railway Congress Association. A special report on this question, with regard to Germany, has been published in the *Bulletin*, January 1930 number, p. 259.

(1) A theoretical proposition for a condensing reciprocating locomotive is given in an article by Mr. Pfaff : « Die Kohlendampfmaschinenlokomotiven mit Kondensation », V.D.I. 1924, p. 997.

The steam turbine, however, is less suitable for locomotive purposes than a reciprocating engine because it does not comply so fully with the requirements of an ideal form of motive power. The curve giving the relationship between speed and power rises to a sharp peak and the maximum power is only developed between certain narrow limits of speed. The efficiency of the turbine is closely dependent on the number of revolutions per minute. It is true that at its normal speed the condensing turbine is more efficient than the present day reciprocating locomotive, but of necessity the number of revolutions of a locomotive must vary widely. Where the gear ratio between the turbine and the driving wheels of a locomotive is constant as in the case of ordinary gear transmissions, the turbine must, while starting a train, run at speeds ranging from zero to the maximum. At a low speed of rotation a steam turbine is less efficient than a reciprocating engine. As in starting, so on steep gradients, reduced speed adversely affects the efficiency of the turbine locomotive.

This difficulty can, of course, be overcome by providing a variable speed gear between the turbine shaft and the driving wheels of the locomotive (this method includes the attempts to use the turbo-electric locomotives) or by other methods such as for exemple by providing multiple turbines for different speeds. Obviously any methods of this kind lead to undesirable complications which increase the first cost and maintenance charges.

15. A valuable advantage of a condensing locomotive lies in the fact that its boiler is fed with pure distilled water so that the boiler does not become scaled. The difficulty caused by scale forming in the small water spaces of ordinary locomotives is one of their weak points, although this trouble has been recently reduced to a certain extent by means of scale preventing devices, based mainly on the principle of precipitating the mineral matter by heating the feed water to a high temperature before introducing it to the boiler. The use of a turbine in a condensing locomotive has also the advantage that the steam does not come into contact with oil so that the condensed water is pure. At the same time freedom from leakage is more easily obtained than in a cylinder, any leakage of steam obviously having a serious effect on the amount of vacuum in the condenser. Another advantage of the turbine is that it gives a uniform turning effort which assists in starting. The co-efficient of adhesion of a turbine engine is therefore greater than that of a reciprocating engine.

16. On the other hand, a disadvantage of the steam turbine is its impossibility of running in the opposite direction. Frequently an auxiliary turbine is provided for running in reverse. This as a rule is a turbine with a less number of stages, as the backward running turbine is only used occasionally, and its economy is not of so great importance and its power may be less. While running in the forward direction, this turbine runs in a vacuum or may be disengaged altogether. Sometimes instead of an auxiliary turbine for running backwards special gear is introduced in the transmission. In either case the means provided for running backwards lead to certain complications compared with the very simple and effective methods of reversing reciprocating engines. The economical speed of a steam turbine is very high, being several thousand revolutions per minute, and for this reason a reduction gearing must be used. This as a rule consists of a train of gear wheels which transmits rotation to a jack

shaft operating the wheels by means of the usual method of connecting rods and coupling rods. The mechanism employed for this is similar to that employed on electric locomotives. This transmission, which is more complicated than that of an ordinary locomotive slightly reduces the mechanical efficiency. Further the introduction of condensation requires a number of auxiliaries of more or less complicated construction. There is in the first place a condenser and a cooling system for transmitting the heat liberated by the condensation of steam to the atmosphere. For auxiliary purposes, fittings such as water pumps and fans are necessary for dealing with the condensed water, the cooling water and cooling air. The condensed water is pumped by means of a special pump from the condenser and then forced by means of a feed pump through a feed water heater back to the boiler. At the same time the air entering the condenser with the steam must be drawn off by special means. In the water condenser a special pump conveys the cold water to the condenser from which it passes to the radiators. In the case of surface condensers a certain amount of the cooling water is lost by evaporation and has to be replaced. The cooling air (in the air condenser) or the air used to cool again the water (in the water condenser) requires as a rule special fans in addition to the natural draught caused by the motion of the engine. In a condensing engine there is no exhaust steam to produce a draught on the fire, and it is therefore necessary to provide a special fan which is usually placed in the smokebox. However, by doing so one of the essential features of the ordinary locomotive is lost, *i. e.* that the quantity of steam produced by the boiler is automatically regulated in accordance with the speed of the engine. The regulation of the draught by the fireman by varying the number of revolutions of the turbine which drives the fan in the smokebox demands constant attention and is less certain. The various pumps and fans are as a rule connected in groups and driven by auxiliary steam turbines or by small reciprocating engines. To sum up, it will be seen that the condensing turbine locomotive requires a larger number of auxiliary machinery than the reciprocating locomotive. It is therefore more complicated and relatively heavier and more expensive.

17. In the category of condensing turbine locomotives with low boiler pressure and the usual type of tubular boiler, five engines come within the scope of our present report :

a) *The Ljungström turbine locomotive of the Swedish State Railways*, constructed by Messrs. Ljungström Aengturbin, at Stockholm, in collaboration with the locomotive building firm of Nydqvist and Holm Trolhättan, Sweden. This locomotive was built in 1926 and has been used since March 1927, in regular passenger service, hauling weights of about 400 tons on the line between Stockholm and Krylbo (161 km. = 100 miles). This engine was built as a result of experience obtained with the first Ljungström locomotive constructed in 1921 which was also tried on the Swedish State Railways and is now withdrawn from service. There are also two other Ljungström locomotives in existence, of which one has been built for the Argentine State Railways in 1925, and the other built in England by Messrs. Beyer, Peacock & Co., Ltd., in 1926;

b) *The experimental Zoelly turbine locomotive built by Messrs. Esscher, Wyss & Co., Zurich*, was constructed by that

firm (Dr. Zoelly) in 1921, in collaboration with the Winterthur Locomotive Works (Ing. Kjellsberg). This is an experimental locomotive, being converted from a reciprocating engine of the 2-6-0 type of the Swiss Federal Railways. When rebuilt the bissel truck was replaced by a four-wheel bogie. This engine has been tested on the Swiss Federal Railways and at the present time is not in service;

c) *The Krupp turbine locomotive* which represents a new development of the Zoelly system. It was built in 1924 for the German State Railways. This engine No. T-18-1001 of the Deutsche Reichsbahn is still under trial;

d) *The Maffei turbine locomotive* constructed by Messrs. Maffei of Munich in 1926 for the Deutsche Reichsbahn on the general principle of the Zoelly locomotive, but considerably improved in constructional details. It is numbered T-18-1002, and has been used on express service between Munich and Nuremberg, since 1929;

e) *The reciprocating locomotive with turbine tender* of the Deutsche Reichsbahn. This was constructed in 1926 by Messrs. *Henschel & Son,* Cassel by rebuilding an old passenger reciprocating locomotive of the P 8 type of the old Prussian State Railways. This engine is still under test.

The principal particulars of these locomotives are summarised in table 1. We will now give a short description of the construction of these turbine engines and of the published results of the tests.

A. — Ljungström locomotive.

18. *General arrangement.* — This engine consists of two vehicles of standard gauge, resembling in external appearance the ordinary engine and tender, but whose functions are essentially different. The leading vehicle, which has 10 carrying wheels, supports a locomotive boiler of the usual type, in the smokebox of which is placed a fan to produce the draught and also an air preheater. This leading vehicle also carries the driver's cab and coal bunker. The second vehicle is the driving vehicle and carries the main turbine with transmission to the driving wheels and also the condenser which is cooled by a current of air with auxiliary fans. The driving vehicle propels the boiler vehicle. This arrangement has been necessary in view of the impossibility of placing a relatively large condenser (with a surface of 2 000 m² [21 500 sq. feet]) on the leading vehicle which carries the boiler. Therefore since the pipe between the turbine and the condenser should be as direct as possible to avoid a loss of vacuum it has been necessary to place the turbine and driving mechanism on the second vehicle. The two vehicles are coupled up by a special type of coupling which ensures that the distance between them remains constant. The two leading axles of the first vehicle and the two trailing axles of the second vehicle form bogies with a lateral play of 60 mm. (2 3/8 inches), on each side. The maximum speed of the engine is 100 km. (62 miles) per hour. However on the Swedish Railways the maximum speed allowed is only 90 km. (56 miles) per hour. The total length over the buffers is 22.800 m. (74 ft. 10 in.). The total wheel base is 18.800 m. (61 ft. 8 in.). The rigid wheel base is 4 m. (13 ft. 1 1/2 in.). This engine can run round curves of a radius of 150 m. (7 1/2 chains). The maximum power is 1 800 H. P.

19. *The boiler.* — The boiler which is of the usual type is pressed at 20 at. (284.5 lb. per sq. inch). The barrel is relatively

TABLE 1.

Low pressure condensing turbine locomotives with normal type of boiler.

BUILDER.	*a*) Ljungström, Stockholm.	*b*) Escher, Wyss & Co., Zurich. Swiss Loco Company, Winterthur.	*c*) Krupp, Essen.	*d*) Maffei, Munich.	*e*) Henschel & Son, Cassel.
Axle arrangement	3 + C2	2 C	2 C 1	2 C 1	2 C + 1 B 2
Working pressure in kgr. per cm²	20	14	15	22	12
Grate area, square metres	3.10	2 32	3 10	3.50	2.62
Heating surface, square metres, (Water side) :					
a) Firebox	14.5	12.3	12 5	13 0	14.35
b) Tubes	119.0	94.1	149.5	146.7	131.93
c) Total	133.5	106.4	162 0	159 7	146.28
Superheater surface, square metres	75	37.8	66.0	51	58 9
Turbines :					
Builder	Ljungström.	Zoelly.	Zoelly.	Melms & Pfenninger.	Zoelly.
Maximum r. p. m.	11 600	7 500	8 500	8 800	8 000
Max. horsepower of turbine	1 800	1 000	2 000	2 000	600
Maximum speed of locomotive in km. per hour	100	75	100	120	86
Diameter of driving wheels on locomotive, in metres	1.530	1.620	1 650	1.750	1 750
Diameter of driving wheels on tender, in metres	—	—	—	—	1.400
Diameter of crank circle, in millimetres	700	650	630	630	630
Weight of locomotive, in metric tons :					
a) Empty	70.3	60.0	103.1	95	73 2
b) Working order	79 5	65.0	112.4	104	79.5
c) For adhesion	49 2	45.6	60.0	60	52 13
Weight of tender, in metric tons :					
a) Empty	62.8	21.5	39.7	36.5	61 6
b) Working order	75.8	39.5	67.5	68	84.6
c) For adhesion	—	—	—	—	34 8

short, the length between the tubeplate being only 3 m. (9 ft. 10 1/8 in.). The air preheater is situated in front of the smokebox. The boiler is fitted with a Schmidt superheater which heats the steam to 380° C. (716° F.). The total weight of the boiler is 21 000 kgr. (46 300 lb.).

20. *The engine.* — The main turbine is of the axial flow type made by Messrs. Aktiebolaget Ljungström Aengturbin, Stockholm. The maximum number of revolutions at 104 km. (64.6 miles) per hour is 11 600; the normal number, corresponding to an engine speed of 89.9 km. (55.9 miles) is 10 000 r. p. m. The speed of the turbine is controlled by the admission valve. Power is transmitted from the turbine shaft by gear wheels to a jack shaft and thence to the leading coupled axle which is concentric with the jack shaft. The reduction ratio is 1 : 32.25. Reversing is obtained by introducing an idle wheel in the gear so that the rotation of the wheels is reversed. The Ljungström engine is thus not fitted with a special turbine for running in the reverse direction. The weight of the turbine is 1 1/2 tons, the weight of the transmission is about 9 tons.

21. *The condenser.* — The condenser is cooled directly by air. It is placed on the driving vehicle behind the main turbine. The condenser consists of a large number of flat tubular elements provided with fins. These tubes are of copper and placed on either side of the vehicle. The steam to be condensed is inside the tubes and the cooling air is drawn past these tubes by means of fans placed in the top of the condenser casing. The fans, whose maximum speed is 750 r. p. m., are driven by one auxiliary turbine (with a maximum of 28 000 r. p. m.) placed at the rear of the driving vehicle. This turbine has a maximum power of about 150 H. P. The weight of the condenser is about 10 tons.

22. *The boiler is fed* by means of two feed pumps which are combined with the condenser water pumps and which are driven by auxiliary steam turbines. The feed pump produces a pressure of about 22 at. (312.9 lb. per sq. inch). The condensed water pump produces a pressure of about 3 at. (42.7 lb. per sq. inch). The power of the auxiliary turbine is about 30 H. P. Between the feed pump and the boiler are two feed water heaters; in the first the water is heated to 90° C. (194° F.) and in the second to 110° C. (230° F.).

23. *Air preheating.* — In the smokebox is placed the Ljungström type rotary air preheater. The preheater is heated by the smokebox gases which it cools down to 150 to 170° C. (302 to 338° F.) while the air is heated to 220° C. (428° F.). The preheater is rotated by means of the auxiliary turbine which drives the draught fan by means of a chain transmission. The heated air is led to the underside of the grate, while a special provision is made for admitting additional air above the grate.

24. *The draught fan* (7 000 r. p. m.) is placed in the smokebox. It is driven by an auxiliary turbine (28 000 r. p. m.) by means of gearing. This turbine is of 90 H. P.

25. *Other fittings.* — The Swedish turbine engine is fitted with compressed air brakes.

26. *Efficiency, tractive effort power.* — The heat balance sheet (see also fig. 1)

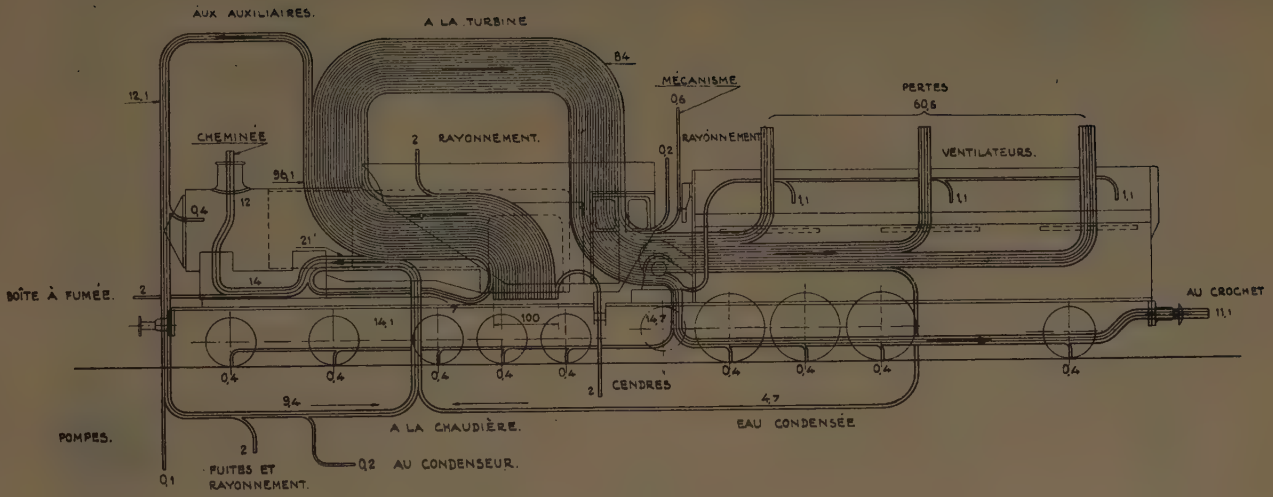

Fig. 1. — Diagram of heat balance for Ljungström turbine locomotive.

Explanation of French terms: A la chaudière = To the boiler. — A la turbine = To turbine. — Au condenseur = To condenser. — Au crochet = At drawbar. — Aux auxiliaires = To auxiliary machinery. — Boîte à fumée = Smokebox. — Cendrées = Ashes. — Cheminée = Chimney. — Eau condensée = Condensed water. — Fuites et rayonnement = Leakage and radiation. — Mécaniques = Mechanical losses. — Pertes = Losses. — Pompes = Pumps. — Rayonnement = Radiation. — Ventilateurs = Fans.

for this locomotive, is given by Messrs. Ljungström as follows :

a) Boiler losses :	
Ashes	2 %
In smokebox	2 %
Up chimney	12 %
Radiation	2 %
	18 %
b) Consumed by auxiliary apparatus :	
Condenser fans	3.3 %
Other fittings	0.5 %
Various losses	2.0 %
	5.8 %
c) Turbine :	
Losses in steam pipe	0.2 %
Losses in mechanism	0.6 %
	0.8 %
d) Heat taken by condenser	60.7 %
e) Mechanical resistance of locomotive	3.6 %
f) Useful work at drawbar	11.1 %

For coal having a calorific value of 7 000 calories (12 583 B. T. U. per lb.) the efficiency of this locomotive corresponds to a consumption of 0.8 kgr. (1.76 lb.) per drawbar horsepower-hour.

Figures 2 and 3 show the tractive effort and power of the engine at various speeds, as quoted by Messrs. Ljungström. The maximum tractive effort at starting is 15 000 kgr. (33 070 lb.); at a speed of 90 km. (56 miles) per hour, the tractive effort is 5 730 kgr. (12 632 lb.) with the regulator full open and 4 000 kgr. (8 818 lb.) with the valve at 0.8 of the full opening.

B. — Zoelly turbine locomotive.

27. *General arrangement.* — The Zoelly turbine locomotive is provided with a tender. The main turbine is placed on the engine in front of the boiler. The condenser was originally placed under the boiler between the frames. As in this position it was inaccessible and could only be cleaned with difficulty a modification has been made consisting of placing two surface condensers on either side of the boiler; the cooling apparatus including the corresponding auxiliaries (fans and auxiliary turbine to drive them) are placed on the tender as are also reserves of water and coal. The draught was originally produced by a current of air led below the grate. However, as this method did not give good results a fan is now employed in the smokebox. This fan which is carried on the smokebox door is driven by a special turbine.

28. *The boiler working pressure* is 14 at. (199.1 lb. per sq. inch). When rebuilt, the boiler was fitted with a Schmidt superheater. The length of the barrel is 3.800 m. (12 ft. 5 1/4 in.).

29. *The turbine.* — The Zoelly six-stage turbine is used; the normal speed is 6 000 r. p. m. corresponding to an engine speed of 65 km. (40.4 miles) per hour. At a maximum speed of 75 km. (46.6 miles) per hour the turbine makes 7 500 r. p. m.; the maximum horsepower is 1 000. For reverse running tender first a special turbine is used which has one single compound disc. Power is transmitted from the turbine shaft by double gearing (ratio 7 : 1 and 4.1 : 1) by means of gear wheels of the Maag type on the jack shaft. The whole transmission is placed on the right hand side of the locomotive.

30. *The condenser.* — The condenser is of the surface type, water cooled. The condensed water at a temperature of about 60° C. (140° F.) is forced by a feed pump

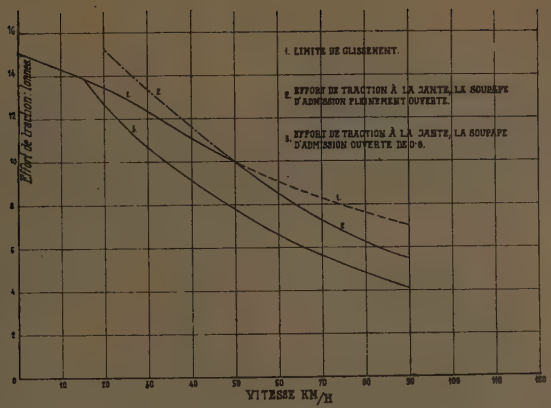
Effort de traction: tonnes
1. LIMITE DE GLISSEMENT.
2. EFFORT DE TRACTION À LA JANTE, LA SOUPAPE D'ADMISSION PLEINEMENT OUVERTE.
3. EFFORT DE TRACTION À LA JANTE, LA SOUPAPE D'ADMISSION OUVERTE DE 0·6.
VITESSE KM/H

Fig. 2. — Ljungström turbine locomotive, Swedish State Railways
Relationship of tractive effort and speed.

Explanation of French terms: 1. = Limit of adhesion — 2. = Tractive effort at wheel tread, regulator full open. — 3. = Tractive effort at wheel tread, regulator 80 % open. — Effort de traction, tonnes = Tractive effort in tons. — Vitesse, km/h. = Speed, km. per hour.

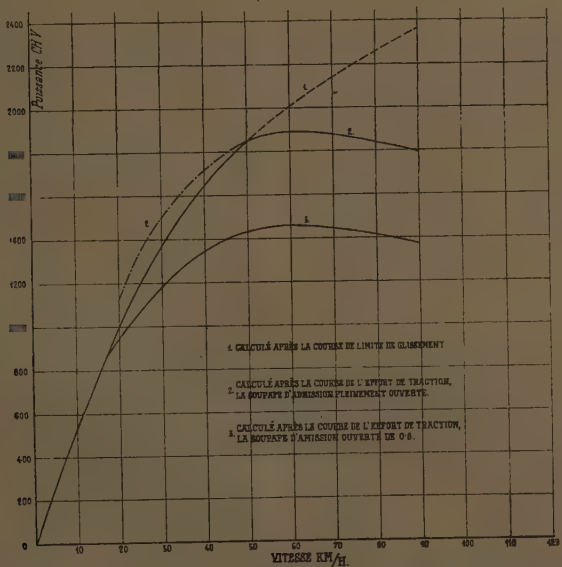
Puissance CH V
1. CALCULÉ APRÈS LA COURBE DE LIMITE DE GLISSEMENT
2. CALCULÉ APRÈS LA COURBE DE L'EFFORT DE TRACTION, LA SOUPAPE D'ADMISSION PLEINEMENT OUVERTE.
3. CALCULÉ APRÈS LA COURBE DE L'EFFORT DE TRACTION, LA SOUPAPE D'ADMISSION OUVERTE DE 0·6.
VITESSE KM/H.

Fig. 3. — Ljungström turbine locomotive, Swedish State Railways.
Relationship between horsepower and speed.

Explanation of French terms: 1. = Calculated from the limit of adhesion. — 2. = Calculated from tractive effort curve, regulator full open. — 3. = Calculated from tractive effort curve, regulator 80 % open — Puissance, ch.-v. = Horsepower. — Vitesse, km./h. = Speed, km. per hour.

through a feed water heater into the boiler. An air pump draws the air from the condenser. The water for cooling the condenser is circulated by a special pump and passes through the condenser and then returns to be cooled.

31. *The cooling apparatus.* — The cooling apparatus was originally of the spray type. This proving unsatisfactory Mr. Zoelly adopted the type of cooling plant proposed by Messrs. Krupp. In the Krupp cooling plant the water slowly runs over a large surface in contact with a current of cold air which carries off the evaporated water. The necessary surface is obtained by means of Raschig rings (thin rings of the diameter and length of about 15 mm. [5/8 inch]). These rings on the grids do not offer any great resistance to the air. The air is propelled by a fan driven by an auxiliary turbine. According to information from Messrs. Zoelly, this fan, when working at full power (85 % of full vacuum), takes about 25 H. P. The heat being mainly abstracted from the cooling water by evaporation, additional supplies of water are required. The amount of water thus used is about half the amount of water used by a piston locomotive of similar power.

32. *Auxiliary apparatus.* — The auxiliary turbines use saturated steam from the boiler. The turbine for the cooling fans and for the pumps are coupled one behind the other and placed on the condenser. The turbine for the smokebox fan exhausts into the feed water heater.

33. *Results of tests.* — The turbine locomotive underwent a series of tests on the Swiss Federal Railways. During the trial runs made with a dynamometer car on the 16th and 17th June 1927, the results shown in table 2 were obtained.

C. — **Krupp turbine locomotive.**

34. *General arrangement.* — This locomotive is also provided with a tender. The turbine is placed at the front of the engine, the condenser consisting of two drums placed transversely beneath the boiler barrel; the cooling apparatus is on the tender. For running in reverse running there is a special turbine on the same shaft as the main turbine with however this difference, compared with the Zoelly turbine that the Krupp locomotive has a separate casing for each of the two turbines. Between these two casings is placed the gear wheel transmission by which power is transmitted to a jack shaft and thence to the driving wheels. Draught is produced by a fan in the smokebox driven by means of an auxiliary turbine. Originally this fan was fitted beneath the smokebox and the smoke was drawn out and forced through long passages.

For this reason a small turbine was placed on the right hand side of the locomotive to drive this fan, while in the induced draught conduit was placed a feed water heater. As this original arrangement did not give good results it was replaced by a fan carried on the smokebox door. The pumps for circulating the cooling water and feed to the boiler are placed on the tender and driven by a special auxiliary turbine. This turbine also drives the brake air compressor. A third auxiliary turbine placed at the back of the tender drives the cooling fan. All auxiliary turbines work with superheated steam. The feed water before entering the boiler passes through two heaters, the first being heated by the exhaust from the turbine which drives the cooling fan; the second, placed under the smokebox, is heated by the gases. The total length of the engine and tender is 24.188 m. (79 ft. 4 5/16 in.).

TABLE 2.

Comparative test runs with Zoelly turbine locomotive, 4-6-0 type, No. 1801 and reciprocating locomotive, 2-3-0 type, No. 1346 of the Swiss Federal Railways.

Weight of reciprocating locomotive No. 1346	90 t.
— turbine locomotive No. 1801	110 t.
Weight of train	258 t.
Number of axles	32

—	Reciprocating loco. No. 1346	Zoelly turbine loco. No. 1801
Date	16-6-1927	17-6-1927
Length of run, in kilometres	215 32	212.08
Time in minutes	217.0	210 25
Speed in km. per hour	59 55	60.60
Work done at drawbar, in kilogrammetres	316×10^6	404.8×10^6
Tractive effort at drawbar hook of tender, in kilogrammes	1 604	1 908
Horsepower at tender drawbar hook	364.6	428.2
Temperature of atmosphere in degrees C.	25°	24°-28°
Relative humidity of air, %	80-90	80-90
Average vacuum, %	...	88-73
Fuel consumption, including shunting, in kgr.	3 085	2 772
Fuel consumption, including coal for firing up, in kgr.	3 385	3 072
Water consumption, not including shunting, in kgr.	21 920	14 900
Steam consumption, not including shunting, in kgr.	21 920	16 050
Steam consumption, including shunting, in kgr.	26 400	21 790
Evaporation of steam in kgr. per kgr. of fuel	8.56	7.85
Temperature of feed water in degrees C.	15°	90°
Fuel consumption per drawbar horsepower, including shunting, in kgr.	2.34	1.85
Consumption of water per horsepower, excluding shunting, in kgr.	16.65	9.93
Consumption of steam per horsepower, excluding shunting, in kgr.	16.65	10.7

35. *The boiler.* — The boiler is of the normal type. When rebuilt the length between the tubeplates was reduced from 5 m. to 4.760 m. (16 ft. 5 in. to 15 ft. 7 in.). One has thus been able to reduce the weight at the front part of the engine. The smokebox has been considerably extended so that it can contain the draught apparatus and the second feed water heater. The draught turbine is of 60 to 100 H. P. The Schmidt type superheater is divided into two parts, the larger of which is for the main turbine while the smaller is for the auxiliary turbines. The steam is heated to 350° C. (662° F.).

36. *The engine.* — The main turbine is of the Zoelly type, the rotor for forward running, placed on the right hand side of the engine, has six stages, the rotor for reverse running (on the left) has three stages. The normal speed of the rotor is 6 800 r. p. m., corresponding to a speed of 80 km. (50 miles) per hour. The maximum power of the main turbine is 2 000 E. H. P. The transmission from the turbine shaft to the driving shaft is by a double pair of gear wheels.

37. *The condenser.* — The surface condenser is divided into two drums, so that it can be more easily accommodated. The condensed water flows to a special reservoir from which it is drawn by the feed pumps. The cooling water passes through the drums and then returns to the cooling plant.

38. *The cooling plant.* — The cooling water runs out in a thin layer along the Raschig rings coming in contact with a current of air drawn in by the fan. The cooled water flows to the lower part of the tender from which it is drawn by the circulating pump to again pass through the condenser. In order to avoid any loss due to the water being carried away by the current of air, when the engine was rebuilt channels were provided to lead the water over the Raschig rings. The air penetrates into the cooling plant by openings in the side of the tender and is drawn in by a fan arranged in a special channel in the centre of the tender.

39. *Auxiliary apparatus.* — The feed pump is of the differential piston type. The pump for the cooling water is of the rotary type made by Messrs. Maffei-Schwartzkopff. Part of the cooling water under pressure passes through an air ejector of the Muller type which serves to draw out air from the condenser. The water thus used returns to the suction pipe of the cooling water pump. The feed water passes through two heaters, the first heats it to 100° C. (212° F.) by the exhaust steam, the second to 130 to 140° C. (266 to 284° F.) by combustion gases. To replace the water lost by leakage and used for heating the train, a small boiler is placed in the dome of the main boiler.

40. *Results of tests* are not yet published. When the engine was ordered a fuel economy of 20 % was guaranteed on a level line and of 18 % on gradients of 1 in 100, compared with a reciprocating locomotive of the same power. According to Lorentz (Dampfturbinenlokomotiven mit Kondensation) it may be expected that a locomotive of this type will have a steam consumption of 4.97 kgr. (10.95 lb.) per indicated horsepower, *i. e.* an economy of about 32 to 36 % compared with a similar non-condensing reciprocating superheater engine and consume fuel of 7 000 calories/kgr. (12 600 B. T. U. per lb.) at a rate of 0.62 kgr. (1.37 lb.) *i. e.* (4 472 calories) per indicated horsepower-hour, corresponding to an economy of 44 to 47 %, and a thermal efficiency of 14.1 %. The German State Railways carried out

certain tests with these locomotives which led to the reconstruction mentioned above, after which they have carried out further tests, the results of which have not yet been published.

D. — Maffei turbine locomotive.

41. *General arrangement.* — The locomotive built by Messrs. Maffei of Munich is provided with a tender. In general, the arrangement is similar to the Zoelly type. The steam turbine is placed at the front of the locomotive below the boiler. Power is transmitted from the turbine by means of gear wheels (with a total gear ratio of 1 : 24) to a jack shaft and thence to the coupled wheels. The transmission is placed symmetrically on both sides of the locomotive.

Condensers are placed on both sides of the boiler. Air is extracted from each condenser by a small ejector while the condensed water is drawn off by a piston pump which is coupled to the feed pump. The draught fan with its small turbine is placed on the smokebox door. The front part of the tender carries a feed water tank of 4.3 m³ (152 sq. feet) capacity, above which is a coal bunker (6.7 tons), while the rear part of the tender carries the radiator (with a surface of 1 500 m² (16 140 sq. feet) and a reserve of cooling water of 20 m³ (4 400 British gallons). Between the coal bunker and the radiator is placed an auxiliary turbine to drive the ventilating fans and cooling water pumps. The maximum speed of the locomotive is 120 km. (74.6 miles) per hour and the normal speed 70 km. (43.4 miles) per hour. The locomotive should be capable of working heavy trains at 100 km. (62 miles) per hour on a level line. The total length of the engine without tender is 13.590 m. (44 ft. 7 in.) and its maximum output 2 000 H. P.

42. *The boiler* is of the normal type, with a working pressure of 22 at. (312.9 lb. per sq. inch), the highest which has up to the present been used on this type. The barrel has a length of 5.200 m. (17 ft. 3/4 in.) between the tubeplates; a Schmidt superheater is provided.

43. *The engine.* — The main turbine, by Messrs. Melms and Pfenniger, consists of one turbine for forward running and one turbine for reverse running, these being both keyed to one common shaft and placed in one casing. The maximum speed of the turbine is 8 800 r. p. m., corresponding to a running speed of 120 km. (74.6 miles) per hour. Power is transmitted from the turbine shaft to a jack shaft by means of gear wheels on either side of the locomotive.

44. *The condenser.* — Two surface condensers are arranged in parallel; the total cooling surface of the condensers is 220 m² (2 368 sq. feet). The condensed water runs into a reservoir from which it is drawn by a pump which is directly coupled to the feed pump; the two pumps are surrounded by a common reservoir of water connected with the feed water reservoir in the tender. The condensate pump passes this water to a water chamber from which it is drawn by the feed pump and forced through two feed water heaters into the boiler. Air is withdrawn from each condenser by means of a steam ejector.

45. *The cooling plant.* — The radiator is divided into a number of compartments in which are 48 cooling elements in all with a total cooling surface of 1 500 m² (16 140 sq. feet). The current of air is upwards while the cooling water is led to two perforated tubes placed above the radiator elements, and collects again at the

bottom after traversing the whole of their surface. The water is forced by a rotary pump placed below the tender frame. The capacity of this pump is 350 m³ (12 360 cubic feet) per hour, against a total pressure height of 14 to 15 m. (45 ft. 11 in. to 49 ft. 2 1/2 in.). Air is introduced by two ventilators placed in the roof of the tender each having an approximate capacity of 25 cm³ (883 cubic feet) per second. The pump and the two fans are driven by a small auxiliary turbine. The turbine under full load makes about 6 300 r. p. m., the number of revolutions of the pump and fans being about 1 000 per minute. Under full load working the pump absorbs 25 H. P. and each ventilating fan 13 H. P. Even when working at full load it is possible to obtain a vacuum of 80 to 90 % in the condenser. For a smaller load the vacuum is still greater.

46. *Auxiliary apparatus.* — The two feed water heaters are placed on either side of the boiler; the first feed water heater is heated by exhaust steam from some of the auxiliary apparatus. The condensed water at a temperature of 45 to 50° C. (113 to 122° F.) is heated to 90 to 95° C. (194 to 203° F.). The second feed water heater is heated from the exhaust steam of the radiator turbine at a pressure of 3 1/2 at. (49.8 lb. per sq. inch) and also by the exhaust steam from the draught fan turbine. The feed water is heated therein to a temperature of 130° C. (266° F.).

The air for combustion is not preheated.

A draught fan is placed in the smoke-box and this draws out the gases and forces them through the chimney. This fan is driven by an auxiliary turbine placed on the same shaft as the fan. The supply of steam to the turbine and the number of revolutions (6 000 to 7 000 per minute) are regulated by the fireman. Steam for heating the train is obtained from the exhaust of the radiator auxiliary turbine which works against sufficient back pressure to effect this heating. The pressure is regulated by the fireman by means of a reducing valve which, when once regulated, maintains the pressure desired. For lighting a small 300-watt 25-volt turbo-dynamo is provided. Westinghouse brakes are fitted.

47. The heat balance as given by Mr. Imfeld, Engineer, of Messrs. Maffei is as follows :

Losses by the chimney.	17 %
Other losses in the boiler.	11 %
Heat rejected to the atmosphere by the radiator.	55.6%
Total losses. . .	83.6%

Consumption for auxiliary apparatus :

Draught fan	0.2 %
Radiator fan and cooling water pumps	0.4 %
Air ejectors for condenser . . .	0.03%
Compressor for brake	0.07%
Feed pump and condensate pump	0.1 %
	0.8 %
Main turbine	15.6 %

At a speed of 70 km. (43.5 miles) per hour, 15 % of the total energy produced by the combustion of coal on the grate is delivered to the turbine shaft. For one H. P. at the turbine shaft it is only necessary to produce 4 050 calories on the grate, *i. e.* to burn 0.58 kgr. (1.28 lb.) of coal calorific value of 7 000 cal./kgr. (12 600 B. T. U. per lb.). It will, however, be as well to wait until these very favourable estimates are confirmed by tests, the results of which are not yet published.

E. — Reciprocating locomotives with condensing turbine tender built by Mssrs. Henschel & Son, Cassel.

48. *General arrangement.* — This locomotive is a rebuild of one of the 38 10/40 series of the Reichsbahn. The tender has been replaced by an entirely new one, while the engine itself has only had some small modifications. The exhaust steam is led from the cylinders of the locomotive by special pipes on both sides of the boiler, and through oil separators to an articulated joint between the engine and tender and thence on to the tender, through a regulating valve, to the steam turbine. The tender also carries condensing gear such as a specially constructed condenser and fans for the air passing through the condenser. Supplies of coal (5.4 m^3 = 190 cubic feet) and water (6 m^3 = 1 320 Brit. gallons) are also carried on the tender. The feed water heater is at the front of the chimney placed high enough so that the feed water may flow from the feed water heater to a special reservoir. The draught fan is carried on the smokebox door. Power is transmitted to the wheels by means of gear to a jack shaft and thence to the driving wheels under the tender. The gear box is placed between the tender frames. The gear ratio between the turbine shaft and the jack shaft is 1 : 24.4. The total length of the engine and tender excluding buffers is 22.917 m. (75 ft. 2 in.).

49. *Boiler.* — No modifications have been made to the boiler of the locomotive. A Betz fan for producing draught has been placed on the smokebox door. The fan is mounted on a common shaft with a turbine which drives it. The steam to and from the turbine is led through jointed pipes which also serve as hinges for the door.

50. *The turbine.* — The turbine for forward running has three stages and is of the Zoelly type. This turbine is mounted on a common shaft with a single stage turbine for reverse running. In order to avoid losses, access to the second turbine is closed by means of an automatic valve. The turbine runs at 8 000 r. p. m. Control of the turbine is automatically effected by a special device connected to the regulator of the locomotive. When starting and on heavy gradients it is possible to admit additional steam from the boiler to the turbine. The turbine is placed at the front of the tender underneath the coal bunker and is easily accessible from the side.

51. *Condenser.* — The surface condenser is of special construction from the designs of Professor Pauer (Dresden), and is placed on the tender close to the steam turbine. Heat is abstracted by the evaporation of the cooling water which runs along the surface of the condenser. The evaporation of this water is assisted by a current of air in the opposite direction to the flow of water across the condenser. The movement of air is caused by three Betz fans arranged in the roof of the tender. Tests made with this condenser have shown that the surface necessary is not much greater that that for a condenser with a separate radiator. The quantity of cooling air and water evaporated does not differ greatly from the Zoelly-Krupp radiator. The vacuum obtained in the condenser is 80 to 85 %. The condensed water is drawn out by the condensate pump and then forced by a feed pump through the feed water heater into the boiler.

52. *Auxiliary apparatus.* — An auxiliary turbine placed on the tender drives a feed pump, the three fans, the condensate

pump and the cooling water pump. A second auxiliary turbine drives a draught fan. These auxiliaries absorb about 65 H. P.

53. *Tests.* — The maximum power which has been obtained by the turbine and which increases the power of the reciprocating engine is 500 H. P. at a speed of 70 km. (53.5 miles) per hour. The maximum tractive effort of the locomotive when starting is 4 200 kgr. (9 260 lb.). The testing department of the Reichsbahn has submitted this locomotive to a series of trial runs, the results of which have not yet been published.

54. To sum up, in Southern and Central Europe two main types of condensing turbine locomotives with normal boilers have been constructed, the Ljungström locomotive and the Zoelly locomotive. The Ljungström locomotive differs more than the Zoelly type from the ordinary arrangement of reciprocating locomotive. It has been considered that this type, in which the driving vehicle propels the boiler vehicle in front of it, is less safe especially when running round sharp curves. Moreover it has been criticised on account of the danger to the footplate staff in case of the rupture of the main steam pipe which passes under the footplate. Experience, however, does not appear to support these criticisms. The method of reversing the running direction by means of the introduction of an idle wheel into the transmission offers great advantages as it dispenses with the reverse running turbine. It would, however, appear better if this wheel were constantly in mesh and provided with a clutch. The Ljungström condenser, which is cooled directly by air, is very simple in principle. In practice, a large number of small elements and joints constitute a source of leakage and frequent repair. In view of the low coefficient of transmission of heat between metal and air the direct cooling by air requires a large condenser surface. The surface of the condenser of the Swedish locomotive [about 2 000 m² (21 500 sq. feet)] is in fact nine times greater than that of the Maffei locomotive (220 m² = 2 370 sq. feet) which has 10 % greater power. On the other hand the Ljungström locomotive does not require a radiator. The Henschel type of condenser is an attempt to combine the two advantages. Direct cooling by air has another disadvantage as, to obtain sufficient cooling effect, it is necessary that the air should have a high velocity. The consumption of energy by the cooling fan is therefore considerably greater than for the evaporating condensers with cooling water.

The tests carried out with these two types of turbine locomotives have shown that they can be used under service conditions. These tests have also shown the economy in coal and water of the turbine locomotive when compared with reciprocating engines of similar power. It may be pointed out that part of the increased efficiency of certain locomotives appears to be due to an increased efficiency of the boiler. The Ljungström locomotive with direct air cooling is also distinguished by consuming practically no water. Practical experience has shown that the economy with turbine locomotives depends to a certain degree on the skill of the staff who have to exercise more care than with the reciprocating locomotive. The regulation of the turbine nozzles and of the draught fan in particular require close attention. As regards maintenance costs at present we do not possess sufficient information. According to general information these expenses seem to be

very considerable. However, one should distinguish between costs due to initial defects and which arise when only one engine of a type exists, and maintenance costs of a permanent nature. The large number of auxiliary apparatus adversely affects both the reliability and the maintenance cost. This is partly compensated by reduced boiler maintenance. In short, up to the present the general advantages of the turbine locomotive have yet to be proved. In this respect, we must await results of the trials in hand and the practical experience obtained in service with recent locomotives. The relatively long time which has elapsed since these were first built and the reconstruction of these experimental locomotives indicate the difficulties which have to be surmounted. However, it appears that condensing turbine locomotives may be used with advantage under certain special cases (in countries where water is scarce or for express trains with a small number of stops).

II. — High pressure locomotives.

55. The efficiency of an ideal steam engine increases with the working pressure, very rapidly for low pressures, but the rate at which the efficiency increases falls off as the pressure increases. For a non-condensing engine the ideal efficiency is 18 % at 15 at. (213 lb. per sq. inch), 24 % at 50 at. (341 lb. per sq. inch), 27.2 % at 100 at. (1 420 lb. per sq. inch), and 28.1 % at 150 at. (2 130 lb. per sq. inch). For a condensing engine the efficiency is 32.2 % at 15 atmospheres, 37.8 % at 50 atmospheres, 39.5 % at 100 atmospheres, and 40.2 % at 150 atmospheres.

56. Obviously, constructional difficulties increase as the pressure rises, and there is therefore a limit of pressure which it is not economical to exceed under present-day conditions. This consideration has led designers to limit the pressure in the boiler to 60 at. (850 lb. per sq. inch) although some have gone to twice this pressure.

57. The properties of steam at this high pressures differ appreciably from those at low pressures. The heat contained in 1 kgr. both of saturated steam or superheated steam at any given pressure decreases as the pressure increases. At the same time the heat of the liquid increases while the heat of vaporisation decreases. The minimum total heat of saturated steam occurs at the critical pressure of 224.2 at. (3 189 lb. per sq. inch) and is equivalent to 499 calories per kgr., while at 25 at. (356 lb. per sq. inch) the total heat of saturated steam has its maximum at 676 calories per kgr. The specific volume of the steam decreases as the pressure increases. At 100 at. (1 420 lb. per sq. inch) and 450° C. (842° F.), the specific volume is approximately one fifth of that at 20 at. (284.5 lb. per sq. inch) and 350° C. (662° F.), so that for high pressure boilers the dimensions of the steam space and the diameters of the steam pipes are proportionately reduced. The saturation temperature of the steam also increases with the pressure. With present-day materials and methods of construction it is difficult to use superheater temperatures above 450° C. (842° F.); therefore the steam is reduced to the saturation point during adiabatic expansion and becomes dump thus reducing the efficiency of the engine. It is therefore advisable to again superheat the steam between the stages of expansion.

58. Even with high steam pressures it is necessary that the boiler should contain

a large volume of water to provide a reserve of heat against rapid variations in the steam consumption during the interval of time necessary for the intensity of combustion to accommodate itself to the demands for steam. However, large quantities of water cannot be carried in high pressure boilers without increasing certain difficulties in construction. The more rapidly the rate of combustion can accommodate itself to the steam consumption the less need the reserve of water be. For this reason, pulverised fuel appears to be suitable for a high pressure boiler provided that it can be successfully applied to locomotives.

59. The heat transference through the walls of a boiler should be as constant as possible and no part should become overheated to such an extent as to impair its safety. This has led to attempts to dispense with any direct contact between the flame and the walls of the boiler by means of what is known as indirect steam heating. For this reason it is advisable in high pressure boilers to use pure water and thus there is a great advantage in using the same water over and over again, *i. e.* to provide a close circuit of water and steam in the boiler. For very high pressures accumulations of bubbles of steam and gases which tend to form in the water on the walls of the boiler are a source of danger, because the conductibility of steam is lower than that of water so that wherever the steam bubbles congregate the temperature of the boiler walls is increased. In this case a constant heat transference may be obtained by adopting a forced circulation of steam and water in the boiler. It is also important that the path followed by the steam bubbles through the water inside the boiler shall not be too long so that the steam may not become too wet.

60. For a high pressure boiler it is necessary to employ suitable materials which retain their strength at high pressures. For this reason it is advisable to use a hard metal of a special quality although a ductile metal is stipulated in the majority of specifications.

61. The special conditions of a locomotive in service require great rigidity of the boiler from the mechanical point of view. The water tube boiler, from the nature of its construction, is less rigid than the ordinary locomotive boiler. For this reason it is necessary to strenghten it by suitable means.

62. Five high pressure locomotives come within the scope of the present report; the three first are reciprocating engines without condenser, while the two last are condensing turbine locomotives; these are :

a) The high pressure (60-at. = 850 lb. per sq. inch) non-condensing reciprocating locomotive of the Winterthur type. This engine was built in 1927-1928 by the Swiss Locomotive Works, Winterthur, to the designs of Mr. Buchli, for experimental purposes. It is a tender locomotive of the 2-6-2 type. It has not been altered much from the ordinary simple expansion locomotive, but the boiler and engine are a type suitable for high pressure steam and are entirely new. All these parts have been carefully designed and tested in the works before assembling on the locomotive. On completion this locomotive was submitted to a series of tests on the Swiss Federal and the Austrian Railways;

b) The high pressure non-condensing locomotive (60 at. = 850 lb. per sq. inch) of the Schmidt-Henschel type. This engine was ordered as an experimental engine by the Deutsche Reichsbahn from Messrs. Henschel & Son, Cassel. It uses

steam at two working pressures produced in two independent boilers. There are three cylinders, one for high pressure and the other two for low pressure. This locomotive has been under test on the Reichsbahn since 1927;

c) The high pressure non-condensing locomotive (120 at. = 1 700 lb. per sq. inch) of the Löffler type. This engine has been ordered for experimental purposes by the Deutsche Reichsbahn from Messrs. Berliner Maschinenbau A. G. vorm. L. Schwartzkopff, of Berlin. In this system the boiler in which the steam and water is circulated by special pumps produces steam at a pressure of 120 at. (1 700 lb. per sq. inch) the steam being expanded in the cylinders to 18 at. (256 lb. per sq. inch), and, after leaving the cylinders, condenses, giving up its heat to a low pressure steam boiler at 15 at. (213.3 lb. per sq. inch). The steam from this boiler is used in the low pressure cylinders. This locomotive is still under construction;

d) The high pressure turbine condensing locomotive (60 at. = 850 lb. per sq. inch) by Messrs. Krupp. This locomotive is of the 4-8-2 type and has a maximum horsepower of 2 500. It was ordered for trial purposes from Messrs. Krupp by the Deutsche Reichsbahn. The steam produced in the water tube boiler is used in a steam turbine without condenser. This engine is still under construction;

e) The high pressure condensing turbine locomotive (225 at. = 3 200 lb. per sq. inch) by Messrs. Maffei of Munich. This locomotive has a Benson type boiler and has been ordered for experimental purposes by the Deutsche Reichsbahn from Messrs. Maffei of Munich. It has not been completed up to the present.

(The principal characteristics and dimensions of the engines under headings *a*) and *b*) are given in table 3.)

A. —Winterthur high pressure non-condensing locomotive (60 at. = 850 lb. per sq. inch).

63. *General arrangement.* — The boiler is relatively short and high so that at the front there is room to accommodate the engine. The steam from the special water tube boiler at a pressure of 50 at. (710 lb. per sq. inch) [approximately 270° C. (518° F.) temperature] is heated to a temperature of about 400° C. (752° F.) and passes to a simple expansion three cylinder non-condensing high speed engine (750 r. p. m. maximum speed). Part of the exhaust steam is used for the first stage of heating the feed water (to 80 or 90° C. = 176 to 194° F.) in a Knorr feed water heater with a heating surface of 7 m² (75.3 sq. feet), exhaust steam from the feed pumps also being used for this purpose. This feed water heater is placed on the side of the boiler. The second stage of heating the feed water (to 250° C. = 482° F.) is obtained by means of a heater with a surface of 65.2 m² (702 sq. feet) using the products of combustion. This feed water heater is placed in the boiler. The high temperature to which the feed water is heated prevents the deposit of scale and sediment in the boiler. The air for combustion supplied beneath the grate, is preheated in a special heater warmed by the products of combustion and placed in the smokebox. In view of the fact that this arrangement had but little effect it was abandoned as being a useless complication. Power is transmitted through the engine crank shaft by means of gear wheels driving on to a jack shaft which drives the coupled wheels of the locomotive. Water tanks are placed

Table 3.

High pressure reciprocating locomotives.

—	*a*/	*b*/
Makers	Winterthur.	Henschel & Son, Cassel.
System	Winterthur.	Schmidt Superheater C°.
Wheel arrangement	1 C 1	2 C
Grate area in sq. metres	1.33	2.47
Closed heating circuit :		
Steam pressure in kgr. per cm²	...	90
Heating surface of water tubes, fire side, sq. metres	...	20.23
High pressure boiler :		
Pressure of steam, in kgr. per cm²	60	60
Heating surface, water side, in sq. metres	97 (1)	39.6
High pressure superheating surface, in sq. metres.	20	40
Water volume at minimum level, cubic metres	2.7	1.76
Low pressure boiler :		
Pressure of steam in kgr. per cm²	...	14
Heating surface, fire side, sq. metres	...	117.6
Low pressure superheater heating surface, sq. metres	...	36.6
Water volume, minimum level, cubic metres	...	3.6
Engine and motion :		
Number of cylinders :		
a) High pressure	3	1
b) Low pressure	...	2
Diameter of cylinders :		
a) High pressure	215	290
b) Low pressure	...	500
Piston stroke, in millimetres	350	630
Gear transmission	1:2.5	...
Diameter of driving wheels, in metres	1.520	1.980
Weight of locomotive, in kgr. :		
a) Empty	62 800	85 620
b) Working order	75 000	92 080
c) For adhesion	48 000	60 190
Weight of tender in kgr. :		
a) Empty	...	28 120
b) Working order	...	66 620
Water capacity, cubic metres	6.2	31.5
Coal capacity, in tons	2.7	7
Total length between buffers, in metres	13.140	21.200 (2)

(1) Including surface of second feed water heater.
(2) Including length of tender.

on each side of the boiler while the coal bunker is placed behind the footplate.

64. *The boiler.* — The water tube boiler consists of two lower drums on each side of the boiler and one upper drum placed in the centre. These drums are connected by three transverse partitions and by a series of water tubes. The various parts of the boiler are electrically welded together. The centre partition divides the boiler into two chambers. The back chamber forms a firebox and is fitted with a grate of ordinary type. In the first chamber are placed the vertical tubes of the steam superheater and the horizontal tubes of the feed water heater, between which flow the products of combustion. Vacuum is produced in the firebox by means of a blast pipe of ordinary type. Numerous washout plugs are provided for cleaning the various parts of the boiler. The superheater and feed water heater may also be easily withdrawn and cleaned externally. The construction of the boiler allows for expansion under the effect of heat. The drums and transverse partitions form a rigid structure from the point of view of mechanical strength. The weight of the boiler is approximately 20.2 tons.

65. *The engine.* — The engine runs normally at 450 r. p. m. and at 700 r. p. m. as a maximum, this latter figure corresponding to a piston speed of 0.8 m. (2.624 feet) per second, and a running speed of 80 km. (50 miles) per hour. There are three simple expansion uniflow cylinders. Poppet valves are provided although the valves only serve to admit the steam, the exhaust being controlled by the piston itself. There are only six degrees of cut-off, 4.9 %, 5.9 %, 7 % , 10 % ,12.5 % and 78 %, the last being used when starting. The back pressure in the exhaust corresponding to the first four cut-offs

Fig. 4 and 5. — Winterthur high pressure locomotive.

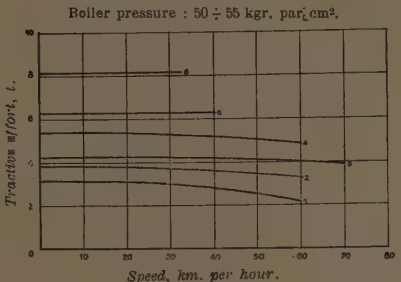

Fig. 4. — Tractive effort as a function of the speed.

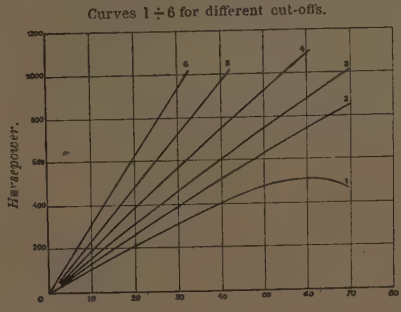

Fig. 5. — Effective horsepower at engine shaft as a function of the speed.

which are most generally used is from 3 to 6.5 at. (42.2 to 92.4 lb. per sq. inch), *i. e.* relatively high in order to obtain sufficient vacuum in the smokebox.

66. *Auxiliary apparatus.* — Steam at reduced pressure is used for the brake air pump and for carriage warming. The locomotive has the ordinary Westinghouse brake.

67. *Tests.* — Both the boiler and engine have been submitted to numerous tests in the works. Later a number of trial runs

were carried out on the Swiss Federal Railways and the Austrian Railways. According to a communication from the Winterthur Works dated June 1929, this engine has already run 30 000 km. (18 640 miles) in regular service. According to the statement of the makers the efficiency of the boiler for a combustion rate of 250 kgr. per m² (51 lb. per sq. foot) of grate per hour is about 80 % and, for a combustion rate of 450 kgr. per m² (92 lb. per sq. foot) per hour the efficiency falls to 70 %, the production of steam being 2 650 and 4 400 kgr. (5 840 and 9 700 lb.) per hour respectively, *i. e.* 2 000 and 3 200 kgr. per m² (410 and 655 lb. per sq. foot) of grate area and 26.5 and 44 kgr. per m² (5.42 and 9.0 lb. per sq. foot) respectively of total heating surface including the surface of the second feed water heater heated by the products of combustion. The tractive effort and the power at the engine crank shaft is shown in figures 4 and 5. The maximum tractive effort is 8 100 kgr. (17 860 lb.). The maximum efficiency of the locomotive at the engine shaft is according to the makers 11.3 % which for a fuel having a calorific value of 7 000 calories/kgr. (12 600 B. T. U. per lb.) corresponds to a consumption of 0.8 kgr. (1.76 lb.) of fuel per brake horse power. Tests have been made between the Winterthur high pressure locomotive and a similar locomotive of the 2-6-0 tender type of the Swiss Federal Railways working at 12 at. (170.6 lb. per sq. inch). The first comparative tests were made in January 1928, the Swiss Federal Railways' dynamometer car being used. The principal results were :

—	*Winterthur to Romanshorn and back.*		*Winterthur to Stein Säckingen and back.*	
Distance	112 km. (69.6 miles).		149 km. (92.6 miles).	
Maximum gradient	12 mm. per metre (1 in 83).		8 mm. per metre (1 in 125).	
Load hauled	242 t. (238.2 English tons).		300 t. (295.3 English tons).	
Number of axles	31		40	
	High pressure.	Low pressure.	High pressure.	Low pressure.
Average speed, per hour	61.8 km. (38.4 miles).	60.7 km. (37.7 miles).	55 km. (34.2 miles).	53.5 km. (33.2 miles).
Coal used	776 kgr. (1 710 lb.).	1 176 kgr. (2 592 lb.).	1 012 kgr. (2 231 lb.).	1 449 kgr. (3 194 lb.).
Water used	5 250 l. (1 155 British gallons).	9 700 l. (2 135 British gallons).	6 550 l. (1 442 British gallons)	12 200 lb. (2 685 British gallons).

The high pressure engine has therefore shown an economy of 35 to 40 % in fuel consumption and of 47 to 55 % in water consumption compared with a normal locomotive. The maximum horsepower recorded on the line Winterthur to Romanshorn was 1 050 horsepower for the high pressure engine and 750 for the normal type.

In June 1928 other test runs were carried out with these two locomotives. The results are as shown in table 4. Tests carried out in 1929 over the Austrian Railways have given equally favourable results.

Compared with one of the Austrian Railways' 629 class locomotives the fuel economy was 30 % and the water about 38 %, the power of the two locomotives ranging between 400 and 500 H. P. The efficiency of the Winterthur locomotive has been particularly satisfactory.

B. — High pressure (60-at. = 850 lb. per sq. inch) non-condensing locomotive, Schmidt-Henschel type.

68. *General arrangement.* — The boiler has been reconstructed in accordance with the designs of the Schmidt Superheater Co. and consists of three independent boilers, as follows :

1. The closed circuit (90 at. = 1 280 lb. per sq. inch) which serves to heat the high pressure boiler.

2. The high pressure boiler (60 at. = 850 lb. per sq. inch).

3. The low pressure boiler (14 at. = 199.1 lb. per sq. inch).

Both the high and low pressure boilers have their superheaters. Steam from the high pressure boiler is expanded in the high pressure cylinder down to 14 atmospheres, and on being exhausted from this cylinder, mixes with steam from the low pressure boiler, the mixture of steam being then used in the two low pressure cylinders and finally escaping through the blast pipe to the atmosphere. The low pressure boiler is fed by a feed pump and injector. Feed water is heated to 90° C. (194° F.) before entering the boiler; the high pressure boiler is fed with water from the low pressure boiler by means of two high pressure feed pumps of special design.

69. *The boiler system* (see fig. 6). — Externally the three portions of the boiler mentioned above form one body similar to that of the Brotan boiler. The closed circuit (90 at. = 1 280 lb. per sq. inch) is composed of water tubes which surround the grate and form the firebox. The high pressure boiler (60 at. = 850 lb. per sq. inch) is placed above the firebox similar to the steam drum of the Brotan boiler.

The low pressure boiler (14 at. = 199.1 lb. per sq. inch) forms the boiler barrel.

The closed circuit consists of water tubes which are expanded at their lower ends into the foundation ring B_1 while the upper ends are expanded alternately into the two upper drums (B_2). From these drums the steam is taken to coils which heat the high pressure boiler. As these tubes form a closed circuit no scale is deposited in them and corrosion is avoided. The high pressure boiler (CH. H. P.) consists of a cylindrical body of nickel steel, the thickness of the walls being 30 mm. (1 3/16 inch). This cylindrical body is carried on tall supports from the expansion brackets on the frame and is connected over a considerable distance (more than one metre) with the low pressure boiler. This arrangement ensures sufficient rigidity of construction. The high pressure boiler is fed with water from the low pressure boiler. Scale forming deposits in the feed water are eliminated either in a precipitating vessel before entering the low pressure boiler or else in the low pressure boiler itself. Moreover the deposit of scale in a boiler where the heat is not transmitted through the walls is unimportant. However, the deposit of scale is to be avoided on the heating coils. The steam from the high pressure boiler passes by the superheater (S. H. P.) placed in the lower flues of the low pressure boiler; it then enters the high pressure cylinder where it expands down to 14 or 15 at. (199.1 or 213.3 lb.

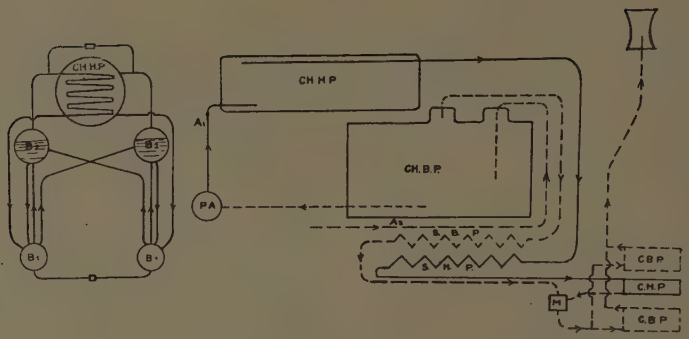

Fig. 6. — Diagram of Schmidt high pressure locomotive, Cassel, Germany.

EXPLANATION :

A) Closed circuit heating coils, 90 kgr./cm².
B_1B_1 = Lower drums.
B_2B_2 = Upper drums.
CH. H. P. = High pressure boiler.

B) Steam generators and engine.
CH. H. P. = High pressure boiler.
S. H. P. = High pressure superheater.
P. A. = Feed pump.
A_1 = Feed water pipe to high pressure boiler.

CH.B.P. = Low pressure boiler.
S. B. P. = Low pressure superheater.
A_2 = Feed water pipe to low pressure boiler.
M = Steam mixing chamber.
C. H. P. = High pressure cylinder.
C. B. P. = Low pressure cylinder.

per sq. inch) and on being exhausted mixes in two special vessels with the steam from the low pressure boiler. The low pressure boiler (Ch. B. P., 14 at.) consists of a boiler barrel of the orthodox type. At the rear end it carries the high pressure boiler, the shell of the barrel being curved so that it can accommodate the high pressure drum. This part of the low pressure boiler, which in cross section is of heart shape, is strengthened by stays and by longitudinal and transverse plates. The low pressure boiler has two domes, one containing the scale collector and the other the regulator. The regulators for the low pressure steam and for the high pressure steam are connected so that they are opened simultaneously by a movement of a common lever in the cab; the steam from the low pressure boiler passes first through the superheater (S. B. P.) placed in the upper flues. It then mixes in the vessels already mentioned with the exhaust steam from the high pressure cylinder, this steam having lost its superheat on account of expansion. By means of this mixture a sufficient degree of superheat is obtained for expansion in the two low pressure cylinders, from which the steam exhausts through a blast pipe.

70. *Engine.* — The engine consists of three cylinders with a common stroke of 630 mm. (24 3/4 inches) the middle cylinder being the high pressure, and the two outside cylinders, the low pressure.

71. *Auxiliary apparatus.* — For feeding the low pressure boiler a Knorr-Nielebock reciprocating steam pump with a capacity of 230 litres (0.882 cubic foot) per minute may be used or alternately an injector of the same capacity. The feed water is heated by exhaust steam from the low pressure cylinders. The high pressure boiler is fed by two special piston pumps made by Messrs. Knorr, placed on the side of the boiler barrel. All the pumps are operated by low pressure steam (14 at. = 199.1 lb. per sq. inch).

72. *Duties of the driver and the fireman.* — The fireman has to feed two boilers (the high pressure and the low pressure) and watch two water levels. Seeing that the water gauge for the high pressure boiler is placed high up, the engine is fitted with another gauge glass of the indirect type placed at the normal height so that the fireman can easily observe the level of the water in the high pressure boiler. In this way the fireman need only occasionally observe the direct reading gauge glass for the high pressure boiler.

The duties required from the driver are the same as those with an ordinary locomotive.

73. *Tests.* — The principle of using steam at two different pressures causes a certain amount of variation as regards the proportional output of the two portions of the boiler. When the pressure increases in the receiver, the pressure also increases in the low pressure boiler and the safety valves lift. The part which the low pressure boiler takes in producing the steam decreases the efficiency of the cycle. The greater the proportion of steam produced by the high pressure to supply the low pressure cylinders the greater is the economy, which conversely is decreased when the proportion of steam from the low pressure steam increases. It is therefore desirable to reduce this difference as much as possible and to completely dispense with the low pressure boiler.

During the tests carried out in 1927, the proportion of steam produced by the high pressure boiler was 50 to 60 % of the total steam produced. At the same time about one third of the total work was done in the high pressure cylinder and two thirds in the low pressure cylinders. On one square metre of heating surface in the high pressure boiler 150 to 240 kgr. (30.7 to 49.1 lb. per sq. foot) of steam was produced in an hour, while one square metre of heating surface in the low pressure boiler only produced 17 to 40 kgr. (3.4 to 8.2 lb. per foot) of steam. After these tests certain modifications were made, in particular the closed heating surface which was originally divided into six elements was combined into one set. A new series of tests were commenced in March 1928. During these tests the calculated pressure of 60 at. (850 lb. per sq. inch) in the high pressure boiler was actually attained while the pressure in the closed circuit for the most part exceeded 90 at. (1 280 lb. per sq. inch) [up to 103 at. (1 464 lb. per sq. inch)]. The consumption of coal having a calorific value of 7 000 calories (12 600 B. T. U. per lb.), per drawbar horsepower-hour on a level line at 80 km. (50 miles) per hour was in the most favourable case 0.98 kgr. (2.16 lb.) when developing about 1 200 H. P. Compared with a 4-cylinder compound of the old Bavarian State Railways of the S 3/6 class (16 at. = 227.6 lb. per sq. inch), the high pressure engine showed an increase in efficiency of 8 % and, compared with the original locomotive which was rebuilt as a high pressure locomotive, the improvement was equivalent to a saving of 30 % (1). As however certain leakages were found in the tubes of the closed circuit further alterations were made after which additional tests were conducted, the results of which are not yet published.

(1) For detailed results of these tests see article by Professor Nordmann *V. D. I.*, 1928, p. 1915.

Date of trial.	Journey.	Length of journey in kilometres.	Class of train.	Locomotive.	Weight of train in metric tons.	Weight of locomotive in metric tons.	Ave spe kilom per h
12. VI. 28.	Winterthur-Romanshorn.	112.2	Fast train.	60 kgr./cm²	343.7	74	55
18. VI. 28.	There and back.	112.2	Fast train.	12 —	351.9	90.5	55
16. VI. 28.	Winterthur-Romanshorn.	112.2	Express.	60 —	347.62	74	44
18. VI. 28.	There and back.	112.2	Express.	12 —	351.9	90.5	52
14. VI. 28.	Winterthur-Stein-Säckingen.	149	Freight train.	60 —	442.22	74	41
15. VI. 28.	There and back.	149	Freight train.	12 —	444.12	90.5	40
19. VI. 28.	Winterthur-St. Gallen.	114.4	Fast train.	60 —	296.7	74	57
19. VI. 28.	There and back.	114.4	Fast train.	12 —	296.7	90.5	50

According to calculations of Mr. Braun, the fuel consumption per horsepower on a level track at an out

C. — Löffler high pressure reciprocating non-condensing locomotive at a working pressure of 120 at. (1 700 lb. per sq. inch).

74. Professor Löffler, of the Polytechnic School, Charlottenburg, is the inventor of a special system of high pressure boiler originally designed for stationary purposes, in collaboration, on the one hand, with the Wiener Locomotive Works, Vienna-Floridsdorf (Austria), and, on the other hand, with Messrs. Mines and Forges, Vitkovice (Czechoslovakia). A trial locomotive built on this system has been ordered by the Deutsche Reichsbahn from Messrs. The Berlin M. A. G., formerly L. Schwartzkopff of Berlin. Professor Löffler's system is based on the following principles.

It is desirable to use steam at high pressure up to 120 or 130 at. (1 700 or 1 850 lb. per sq. inch) if present day materials can be made to withstand the increased temperature of about 500° C. (932° F.). A natural circulation of water and steam in the boiler caused by the difference in the specific weights of hot water and cold water is not however sufficient for very high pressures. In the Löffler system, forced circulation is provided by a special pump for dealing with high pressure saturated steam. At low pressures, this pump absorbs a relatively large amount of power : for pressures up to 20 at. (284.5 lb. per sq. inch), it takes

k done at drawbar n accordance ith diagram		Fuel consumption			Water consumption			Steam evaporation per kgr. of fuel, in kgr.
ne-res.	Horse-power.	total, in kilo-grammes.	per drawbar horsepower-hour, in kgr.	Economy, %, for high pressure locomotive.	total, in kilo-grammes.	per drawbar horsepower-hour, in kgr.	Economy, %, for high pressure engine.	
545	715	860	1.2	35.5	5 600	7.84	51	6.5
230	671	1 252	1.86	...	10 700	15.9	...	8.55
795	1 045	1 206	1.15	30.5	9 350	8.95	36	7.75
750	1 026	1 693	1.65	...	14 400	14.0	...	8.5
850	811	1 119	1.38	25 5	8 400	10.3	38.3	7.5
630	837	1 548	1 85	...	13 950	16.7	...	9.0
540	691	787	1.14	38.4	6 000	9.5	42.5	8.4
420	635	1 176	1 85	...	10 500	16.5	...	8.95

. P. is about 1 kgr. while the consumption of a normal type engine of the same power is about 1.5 kgr.

more energy than the boiler can produce. At 40 at. (569 lb. per sq. inch) the energy required by the pump is about 20 % of the energy of the steam, and it is only at 80 at. (1 138 lb. per sq. inch) that the proportion used by the pump falls below 3 %, and, at a pressure of 130 at. (1 850 lb. per sq. inch) below 2 %. At this pressure the amount of energy used by the steam pump is already less than that of the feed pump. The circulation of the steam in the Löffler high pressure system is shown in figure 7. The saturated steam is produced in the high pressure boiler (CH. H. P.) and is forced by the pump P to the superheater S. H. P., which is directly heated. The superheated steam returns from the superheater and enters the water in the high pressure boiler. Only a small portion of the superheated steam is led off to the engine V. Although the quantity of steam returning to the boiler is less than the quantity leaving, this steam is at a very high temperature, so that it is able to evaporate into saturated steam the whole quantity of water necessary for the engine C and also for indirectly heating the high pressure boiler. The steam which is used in the high pressure cylinders expands down to 18 at. (256 lb. per sq. inch), and after leaving the cylinders is condensed in the tubes of a special low pressure boiler, which is like a surface condenser and which also serves to produce the low pressure steam [about 15 at. (213.3 lb. per sq. inch)]. The condensed

water after passing through the feed water heater, supplies the high pressure boiler which thus only uses distilled water, the oil from the cylinders being removed by an oil separator. The water is

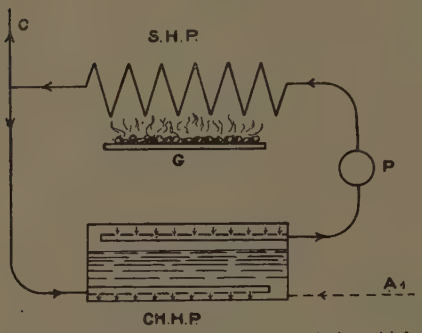

Fig. 7. — Diagram of steam circulation, high pressure portion, Löffler system.

EXPLANATION :

CH. H. P. = High pressure boiler.
P. = Saturated steam pump.
S. H. P. = High pressure superheater.
C. = Steam pipe to high pressure cylinders.
A_1 = Feed water pipe.
G. = Grate.

heated to a temperature such that it is only necessary to add about 50 calories per kilogramme (90 B. T. U. per lb.) to transform it to saturated steam. At the plant erected at Wiener-Neustadt, in order to carry out tests for the Löffler locomotive, the feed water is heated in two stages, first in a surface heater by means of a low pressure steam, and then by means of combustion gases (up to 280° C. = 536° F.). The steam produced in the low pressure boiler passes through a low pressure superheater, expands in the third or low pressure cylinder and then escapes through a blast pipe into the chimney, producing the draught as in an ordinary locomotive.

75. According to the descriptions published up to date of this proposed locomotive, the boiler consists of a number of systems of water tubes. The combustion chamber over the grate is surrounded, first by the tubes of the direct heated high pressure superheater, then comes the low pressure superheater, the high pressure feed water heater and finally the air preheater. The two cylindrical drums of the high pressure boiler are placed outside on both sides of the grate. The low pressure boiler heated by the exhaust steam from the high pressure cylinders is placed in front of the smokebox of the high pressure boiler; in front of this boiler is placed the oil separator and the feed water heater for the low pressure boiler. The arrangement of the engine is shown by figure 8. This engine is still under construction and no tests have yet been made. According to Professor Löffler who bases his opinion on experience gained with stationary boilers of this type, it is hoped that it will realise an economy of about 50 % of coal and water over the best present day locomotives. At the same time the weight and dimensions of the locomotive will be about the same as for an ordinary locomotive, and the price will not be greatly increased.

D. — High pressure condensing turbine locomotive (60 at. [850 lb. per sq. inch] working pressure) by Messrs. Krupp.

76. *General arrangement.* — The water tube boiler is fitted with two steam superheaters, one of which is sufficient for the average degree of expansion; two feed water heaters, one of which is heated by combustion gases and the other by exhaust steam and an air pre-heater. The draught is produced by a fan in the smokebox driven by a special auxiliary turbine. A

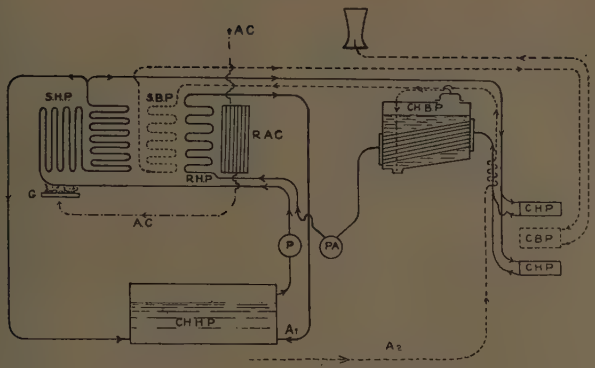

Fig. 8. — Diagram of Löffler locomotive.

EXPLANATION :

CH. H. P. = High pressure boiler (120 kgr. per cm²).
P. = Saturated high pressure steam pump.
S. H. P. = High pressure superheater.
C. H. P. = High pressure cylinders.
P. A. = Feed pump for high pressure boiler.
R. H. P. = Feed water heater (high pressure).
A_1. = Feed water pipe to high pressure boiler.
CH. B. P. = Low pressure boiler (15 kgr. per cm²).
S. B. P. = Low pressure superheater.
C. B. P. = Low pressure cylinder.
A_2. = Feed water pipe to low pressure boiler.
A. C. = Air for combustion.
R. A. C. = Air pre-heater.
G_r. = Grate.

surface condenser is placed at the front of the locomotive; behind this is arranged a group of three main turbines which drive the wheels by means of a train of gear wheels and jack shaft. The cooling arrangement, which is similar to that of the Krupp turbine engine with 15 at. (213.3 lb. per sq. inch) working pressure, is carried on the tender.

77. *The boiler.* — The boiler is constructed after the principle of the Thornycroft-Schulz marine boiler. It consists of five cylindrical drums connected by a series of water tubes. Two of these drums are placed at the bottom and two at the top of each side of the locomotive; the fifth serves as a steam dome and is placed above the middle. These drums are protected from direct heating. The products of combustion heat the tubes of the two steam superheaters, of the second feed water heater and of the combustion air pre-heater. These parts are partly located in a cylindrical body forming a prolongation of the boiler. The boiler is reinforced by a metal structure which gives it greater strength from a mechanical point of view.

78. *The engine.* — The builders have tried to overcome the essential disadvantage of the steam turbine, in that its power curve has too pronounced a peak, by using three steam turbines. Two of these turbines work at speeds of over 45 to 50 km. (28 to 31 miles) per hour and are placed one behind the other as high and low pressure turbines. At speeds of less than 45 to 50 km. per hour, an additional low pressure turbine similar to the other is brought into use. In this way the maximum horsepower of 2 500 is obtained, even at low speeds. The second low

pressure turbine can also be used for running in the reverse direction by suitable gearing. By means of this arrangement one obtains the advantage of being able to develop a large power both at high and low speeds. On the other hand, the construction is complicated, as there are the large turbines and a transmission system consisting of a series of gear wheels and two couplings. The turbines are of the Zoelly type built by Messrs. Escher-Wyss of Zurich.

79. *The surface condenser* is arranged across the frames underneath the smokebox in front of the turbine.

80. *The cooling apparatus* is carried on the tender. The construction of the condenser and cooling apparatus is similar to that of the Krupp 15-at. turbine locomotive.

E. — High pressure condensing turbine locomotive [225 at. (3 200 lb. per sq. inch) working pressure] by Messrs. Maffei.

81. The Deutsche Reichsbahn has ordered from Messrs. Maffei, Munich, an experimental locomotive with a boiler of the Benson system. The water is heated up to its critical point, where it is converted into steam without ebullition and without any increase in the specific volume. A detailed description of this locomotive has not yet been published.

* * *

82. Of the five locomotives which have just been mentioned, only two have been completed, the Winterthur engine and the Henschel-Schmidt. The efficiency of the boiler of these two engines is slightly lower than that of the best locomotives of ordinary type in use today. On the other hand the efficiency of the engine is very good, so that the overall efficiency exceeds that of the best normal locomotives. By comparison of engines of the same power of normal type, these two locomotives show a fuel economy of about 30 %. The consumption of fuel having a calorific value of 7 000 calories (12 600 B. T. U. per lb.) is as low as 1 kgr. (2.2 lb.) per drawbar horsepower-hour. The fuel consumption per unit of power is slightly less favourable in the Henschel locomotive. The means by which the economy has been obtained seems, on the other hand, much more simple in the Winterthur locomotive. Whereas the Henschel engine generates steam at three pressures and expands it in two stages, the Winterthur boiler is a simple water tube boiler and the steam utilised by simple expansion in a small high speed engine with three cylinders and a simple valve gear. This new type of steam locomotive, which is closely related to automobile practice, appears to be a very simple and inexpensive method for high pressure locomotives. Simple expansion, however, has the drawback that the steam becomes damp at the end of the expansion period and causes well-known losses. Both the Winterthur and Henschel engines have the advantage of exhausting direct to the atmosphere, so that the advantage of automatically regulating the evaporation in the boiler in accordance with the power demand is still retained.

The results obtained with the Winterthur locomotive seem to point out the most promising method for the future, as a considerable increase in efficiency has been obtained by very simple means while retaining the best characteristics of the present-day locomotive. The Winterthur locomotive marks the first step in this new direction, and naturally is capable of improvements.

The results of the Krupp high pressure turbine locomotive are not yet known. Further, the interesting engines of the Löffler and Benson system have not yet been tested, and it will be premature to pass any opinion upon them.

III. — Diesel locomotives.

83. A number of small Diesel locomotives for secondary purposes have been built. Their construction resembles to a greater or less degree that of automobiles, and we will only make brief reference to them in this report. Our attention is mainly directed to attempts to emply the Diesel engine for main line locomotives of at least 1 000 H. P.

84. At the present day, Diesel engines are employed in various industries for powers greater than those developed by present-day locomotives. It as been possible to gradually effect considerable reduction in the weight of the Diesel engine, which was originally too great to allow its use on locomotives. In the high power Diesel locomotives, engines have been employed having a weight of 20 to 30 kgr. (44 to 66 lb.) per horsepower; for aviation there are even Diesel engines weighing less than 5 kgr. (11 lb.) per horsepower. At the same time, the Diesel engine has a higher efficiency than any other practical form of heat engine. This efficiency exceeds one third.

85. However, the characteristics of the Diesel engine differ essentially from that of an ideal form of motive power. The Diesel engine can only work if the piston has a fairly high velocity (as a rule more than 0.5 m. [19.685 inches] per second), seeing that a low rate of revolution does not produce sufficient compression in the cylinder to produce the high temperature necessary to ignite the fuel. For this reason, in starting a Diesel engine, it is necessary to employ an external source of power to produce a piston speed sufficiently high for the engine to work itself. When starting, the tractive effort of the Diesel engine is consequently negative. If the Diesel engine were connected to drive directly on to the wheels of a locomotive in the ordinary way, it would be necessary to also provide a source of auxiliary power to produce the large tractive effort necessary for starting. Another disadvantage of the Diesel engine for railway work is that it does not operate in a reliable and economic manner, except within certain rather narrow limits of power. The turning moment of the Diesel engine is therefore almost constant, that is, the engine is by no means flexible. In the case of direct transmission to the wheels, it is therefore impossible to vary the tractive effort of the Diesel locomotive to the wide degree necessary for railway purposes. The Diesel engine is also incapable of any appreciable overload. If the average pressure is increased above 9 at. (128 lb. per sq. inch) in a four-stroke engine, or above 7.5 at. (106.6 lb. per sq. inch) in a two-stroke engine, the power falls off considerably. The maximum power of the Diesel engine is only obtained at the maximum speed of revolution. When the engine is direct coupled to the driving wheels, the maximum power can only be obtained if the engine is running at its maximum speed. This condition is very inconvenient for goods trains, in which the maximum power should be obtained at the relatively low speeds of 20 to 30 km. (12.4 to 18.6 miles) per hour.

86. Therefore, in order to use a Diesel engine for locomotive purposes, it would be necessary either to modify the construction and operation of the engine so

that it more nearly approaches the ideal form of motive power to allow a direct drive on to the wheels, or else to provide variable transmission between the engine and the driving wheels so that the number of revolutions and the tractive effort could be varied over the range necessary for railway purposes. Up to the present, only the second method has been applied in practice. At present there are no Diesel locomotives with direct drive on to the wheels, although it is true that the first large Diesel locomotive, built in 1912 in Switzerland by Messrs. Sulzer Brothers in collaboration with Messrs. Borsig of Berlin, had a direct drive, but it did not prove practicable for railway service. For this reason, the question of the transmission between the shaft of the engine and the driving wheels is particularly important, and it is this which is the principal feature of the Diesel locomotive. This type of engine requires a variable gear so that the two factors on which the power depends, namely, the number of revolutions per minute and the tractive effort may be modified as required by continuous variable gear, or at any rate by a sufficient number of steps. Transmission should also enable the engine to run completely free of the road wheels, and should, if necessary, allow the locomotive to run in the reverse direction, although it is also possible to reverse the direction of the Diesel engine itself.

87. It is for this reason that, instead of providing a mechanical drive from the engine shaft to the wheels, other more flexible forms of transmission have been employed, notably, *electric*, *hydraulic* and *compressed gas*. In all these cases the Diesel engine drives a generator which supplies energy for the transmission, this in turn being transformed, in the corresponding motor, in mechanical power acting on the wheels of a locomotive. It is therefore necessary to equip the locomotive with a threefold unit, namely, Diesel engine, transmission generator and transmission motor. It goes without saying that a solution of this type entails an increase of weight and a high first cost. In motor vehicles the same effect is obtained by using a simple mechanical transmission by gear wheels and shaft, but in view of the large forces which have to be transmitted, this method offers difficulties in the case of Diesel locomotives. In spite of this, it has been done, and mechanical transmission constitutes a quarter of the types in use.

1. — Electric transmission.

88. From a technical point of view, up to the present, electric transmissions have best fulfilled service requirements. This type of transmission was first employed in Sweden, in 1913, on a Diesel-electric rail car. The Diesel Rail Car Co. (Diesel Electriska Vogn Aktiebolaget) delivered a series of rail cars of this type in Sweden, Denmark, France and Tunisia. Similarly, Messrs. Sulzer Brothers, of Winterthur, and Messrs. Brown, Boveri & Co. of Mannheim, have since before the war used electric transmission on the Diesel rail cars which have been supplied to the Prussian State Railways. This transmission can be arranged either for a constant or varying engine speed. In the first case, the tractive effort is controlled solely by varying the excitation of the generator. In the second case, the tractive effort is controlled both by varying the magnetic field and by varying the number of revolutions of the generator. In existing examples, the Diesel engine drives a direct current generator. The current produced is used in electric motors driving on the wheels. In view of

their suitable characteristics for railway work, series motors are used with advantage. These are controlled, as a rule, by the modified Ward-Leonard system. Reversing is effected by changing the direction of current in the armature, the direction of current in the generator and in the field windings of the motors remaining unchanged. This system has been used on the Swedish and Swiss rail cars and also on the Russian Diesel-electric locomotive No. 001.

89. The advantages of electric transmission are as follows : the possibility of adjusting the tractive effort in a continuous and regular manner, very reliable operation, low maintenance costs and the capability of using this type of transmission for high powers. The efficiency of electric transmission is very high and may be as much as 85 %. On the other hand, electric transmission is very heavy and expensive. The weight of electric transmission for the large locomotives built is 26 to 36 kgr. (57.3 to 79.3 lb.) per horsepower. The Diesel-electric locomotive costs nearly twice as much as a steam locomotive of the same power. Further, the electric transmission will eventually limit the power which can be obtained from a Diesel locomotive. The heating up of the motors fixes a limit to the tractive effort. For this reason Diesel-electric locomotives built for ordinary services are not suitable for roads with long gradients in mountainous countries. Further, the strength of the field limits, in some cases, the tractive effort, which renders these locomotives less suitable for express trains. However, with these exceptions electric transmission can be employed with advantage for both passenger and goods trains. By reason of its perfect flexibility it is also very suitable for shunting locomotives.

2. — Hydraulic transmission.

90. Electric transmission may be obtained by arranging that the Diesel engine drives a centrifugal pump, which forces liquid under pressure to turbines coupled to the driving wheels of the locomotive. The disadvantage of hydraulic transmissions lies in the fact that they include parts consisting of small nozzles. The continuous passage of liquid through these nozzles causes them to heat up and modifies their action. Further, the inertia force of the liquid plays an important part. Due to sudden changes in its motion, it produces dangerous shocks and stresses. For this reason these transmissions are more suitable for transmitting a large amount of power intermittently rather than constantly. These disadvantages become the more serious, as it is necessary to run at high speeds so that the transmission gear shall not be too large. A number of hydraulic transmissions have been constructed, as for example, the Janney, Lentz, Rosen, Schumacher, Huwiller, etc. types. The efficiency of the hydraulic transmission is inferior to the electric transmission, being as a rule from 60 to 70 %.

91. Up to the present, hydraulic transmissions have only been used for powers less than 400 to 500 H. P. A small 30-H. P. Diesel locomotive with Lentz transmission was built in 1921 by Messrs. A. Gmeinder & Co. of Mosbach (Germany), which later became Badische Motor Lokomotivwerke A. G. In 1923, this firm, in collaboration with the Maschinenbau Gesellschaft, Karlsruhe, built a 150-H. P. Diesel locomotive. During the same year the Grazer Maschinenfabrik, in Graz (Austria), built a Diesel locomotive of 60 H. P. The same firm constructed for the Austrian State Railways a 200-H. P. Diesel lo-

comotive, the engine making 400 r. p. m., there being 14 speeds up to a maximum of 45 km. (28 miles) per hour. Messrs. Linke-Hofmann Lauchhammerwerke A.G., Breslau, built, in 1924, a 400-H. P. Diesel locomotive with Lentz transmission. The Deutzer Motorenwerke at Cologne-Deutz, acting with Messrs. Henschel & Son, Cassel, constructed several types of Diesel locomotives having Deutz engines of 250, 400 and 550 H. P. and Lentz transmission. In Sweden, Messrs. Kalmar-Verkstadsaktiebolag, of Kalmar, built a Diesel locomotive of the 2-4-2 type of 300 H. P. with Rosen transmission, which is in service on the Kalmar Railway between Kalmar and Nybro. The firm Berliner Maschinenbau A. G., formerly L. Schwartzkopff, of Berlin, have built an experimental locomotive with maximum indicated horsepower of 220, with hydraulic transmission of the Schwartzkopff-Huwiller type, etc., etc.

3. — Compressed gas transmission.

Transmissions of this type have arisen from the idea of using the Diesel motor to compress gas working in the cylinders of the locomotive. The ordinary size of locomotive cylinders is not always suitable for this method of transmission. In spite of this fact, several schemes have been proposed, since before the war, on this system. Air was the first gas to be proposed for use in locomotive cylinders (in 1908 by Messrs. Thermolokomotivgesellschaft : Diesel-Sulzer-Klose in Germany, and in 1910 by Stuckenberg in Russia). The same principle is the foundation of the scheme put forward by Messrs. Esslingen and M. A. N. for the Reichsbahn. Compared with steam, the temperature of air increases much more rapidly during compression, and conversely the temperature falls much more rapidly during expansion. If air compressed to the pressure generally used in ordinary locomotives, very high temperatures are produced, sufficient to ignite the lubricating oil. Therefore it is necessary to cool the air during compression. For this reason compression in several stages is necessary. The air may also be cooled by the direct injection of water (M. A. N. system). On the other hand, when the air expands from a pressure of 12 at. (170.7 lb. per sq. inch) to atmospheric pressure, it becomes very cold (about — 50° C. = — 58° F.). The air therefore has to be heated during expansion. For this purpose it is advantageous to use the exhaust gases. One can also use, instead of air, the exhaust gases for the Diesel engine, either exclusively, as done by Messrs. Görlitzer Masch. Fabr., in Germany, or else mixed with steam (Zarlatti in Italy) or still to use the exhaust gases mixed with air and steam. These mixtures have the disadvantage of being impure. Finally, steam has been used exclusively as a working substance, the pressure being obtained by a compressor driven by the Diesel engine, (Cristiani system). The compressed steam is however heated by the exhaust gases from the Diesel engine, to be expanded in the cylinders of the locomotive and enters into a low pressure receiver where it is cooled by atmospheric air circulated by means of fans from which it again passes to the compressor. The compressor is directly driven by the Diesel engine, the whole energy being utilised for compressing the steam. The Diesel engine and compressor replace the steam boiler of the ordinary locomotive. The steam works in a closed circuit. An experimental engine of 450 H. P. on this principle has been built by Messrs. Kraus & Co. at Linz (Austria). An advantage of this type of transmission arises from the fact that to heat the working fluid,

the exhaust gas, and if necessary, the water from the cylinder jackets can be used. In this case it is possible to increase the thermal efficiency of the locomotive. However, neither the construction nor operation have, up to the present, been solved in a satisfactory manner.

4. — Mechanical transmission.

93. Mechanical transmission is by means of gear wheels arranged in a gear case on similar lines to automobiles or rail cars. Further, it is necessary to use a clutch which allows the Diesel engine to be completely free from the driving wheels of a locomotive. This clutch should be capable of being engaged and disengaged as far as possible without shock. It is particularly important when engaging the engine which is running with the driving wheels at rest that the locomotive should not start with a jerk, which might part the train or slow down the speed of the Diesel engine below the limit at which it can work, that is to say, to stop the engine. For this reason the two parts of the clutch should, in the first place, slip one upon the other so that when the clutch is first engaged, the clutch absorbs the whole of the power and gradually transmits this in an ever increasing degree to the driving wheels of the locomotive. Various clutches of this kind have been proposed. For example, the Lipetz pneumatic clutch. For one large Diesel locomotive with mechanical transmission constructed up to the present, that is to say, the Russian 1 200-H. P. locomotive, a magnetic friction clutch is used.

94. Up to the present we have been considering the ordinary Diesel engine, which is by no means flexible and requires a flexible transmission for the whole of its power. It is however possible, within certain limits, of about 15 %, to vary the power of the engine. In late years attempts have been made to appreciably increase the flexibility of the Diesel engine. There are actually in existence Diesel engines which can work in a reliable manner between the limits of 50 to 1 000 revolutions with mean effective pressures of 2 to 9 at. (28.4 to 128 lb. per sq. inch). There are consequently certain limits of speed and tractive effort within which the Diesel engine can drive the wheels of a locomotive without difficulty by means of direct transmission. It is only outside these limits that a flexible transmission is necessary. In this way it is possible to eliminate to a large degree the transmission losses, which would otherwise be inevitable. On this basis *partial transmissions* have been constructed in which the energy is in part transmitted by direct mechanical means, and in part by an auxiliary transmission. This type necessitates smaller generators and motors, and the efficiency is higher. The partial transmissions have not, up to the present, been brought into practical use for locomotives. The Winterthur Locomotive Works have proposed an interesting transmission of the Schneider type of 500 H. P.; however, this transmission has not been used on a locomotive. It may also be possible to employ two Diesel engines, one of which with a flexible transmission would be used for starting up, and the other with direct transmission would only come into operation when the engine was running at normal speed.

95. In addition to the transmission question, another important problem for Diesel locomotives is the question of cooling. The products of combustion in a

Diesel engine have a temperature of 1 700° C. (3 100° F.) and for this reason all the parts which are in contact with these gases, such as the pistons, cylinders and covers, exhaust valves, and the first portion of the exhaust pipe, require thorough cooling. Water is used as a cooling agent, or in some cases oil also for certain parts. The quantity of heat which must be carried off is little more than 1/3rd of the total heat contained in the fuel burnt, that is to say, almost one-third of the heat which has to be carried off from the condenser of the steam turbine engine of equal power. For 1 000 H. P. the amount is slightly more than 630 000 calories (2 500 000 B. T. U.), and as in the case of the condensing turbine locomotive, efficient cooling is essential for a Diesel locomotive. The condenser must be kept within the dimensions and weight permissible, and should be capable of standing up to service conditions.

96. Finally, another important question is the type of Diesel engine. The Diesel engines used for locomotive purposes are constructed of the three following principal types : single acting four-stroke engines, single acting two-stroke and double acting two-stroke. In order to keep down the weight, it is necessary to select an engine running at a high speed. In the present state of development, the most suitable number of revolutions appears to be between 700 and 750 per minute. At a speed of 720 r. p. m., the four-stroke engines have for the normal load about the same efficiency as the two-stroke, while for an overload the four-stroke engines have the higher efficiency. The double acting two-stroke engines have not up to the present been built for large powers. A difficulty in placing them in the ordinary vertical position arises from the fact of their greater height. Diesel engines are as a rule started up by means of compressed air. With electric transmission it is a also possible to start the engine electrically, the electric generator being used temporarily as a motor, taking current from an auxiliary battery of accumulators. The fuel is injected into the cylinders by compressed air. Diesel engines are also now built without a compressor in which the fuel is injected into the cylinders by mechanical means. These engines are lighter and have a somewhat greater efficiency and are less affected by any alteration in the mean pressure on the piston. The most suitable engine for Diesel locomotives now appears to be the four-stroke solid-injection type with a speed of about 750 r. p. m. by which means the weight can be kept down to about 10 to 12 kgr. (22 to 26.4 lb.) per H. P. The large locomotives constructed up to the present, however, still use four-stroke engines with compressors.

97. In designing Diesel locomotives, it is necessary, as in the case of the electric locomotive, or the turbine locomotive, to calculate the critical speed at which the oscillations of the locomotives may become dangerous. Care must be taken that this critical speed does not coincinde with the ordinary running speeds.

98. In the countries dealt with in the present report, three large Diesel locomotives have been built.

a) 2-10-2 Diesel locomotive No. 001 with electric transmission for the Soviet Railways, with a maximum horse-power of 1 200 built in 1924 by the Maschinenfabrik Esslingen, to the designs or Professor Lomonosoff. The various parts were chosen as having already given good results, namely, the M. A. N. Diesel engine

the electrical equipment by Messrs Brown-Boveri of Baden, Switzerland, etc., electric transmission being selected as being the most reliable. This locomotive has undergone numerous tests since 1925 and is in regular service on the Soviet Railways;

b) The Diesel engine with mechanical transmission of the 4-10-2 type, No. 005, of the Soviet Railways with a maximum horse-power of 1 200, built in 1926 to the designs of Professor Lomonosoff by the Hohenzollern A. G., Dusseldorf, After numerous tests, the locomotive is in regular service on the Soviet Railways

c) Diesel locomotives of the 4-6-4 type, with pneumatic transmission built by the Maschinenfabrik Esslingen to the order of the Deutsche Reichsbahn. This locomotive is now under construction.

The principal particulars of these locomotives are given in table 5.

A. — *Diesel locomotive with electric transmission No. 001 of the Soviet Railways.*

99. *General arrangement.* — The locomotive was originally a single vehicle. After the early tests, a second vehicle (8-wheel tender) was added to carry part of the cooling apparatus. In this way the weight on the driving axles was reduced from 19.5 tons of 17.7 tons; the load on the carrying axles was on the other hand increased from 13.1 tons to 14.3 tons. During the winter it is not necessary to cool the Diesel engine to such a degree as during the summer, and the tender may be dispensed with. The Diesel engine is placed in the middle of the locomotive, its main shaft being arranged longitudinally. The compressor is direct coupled to the Diesel engine; the continuous current generator and exciter are coupled to the main shaft by means of an elastic coupling. The current operates five series motors each driving one of the driving axles by means of gear wheels.

100. *The Diesel engine* is of the M. A. N. four-stroke type with six cylinders, and is not reversible. Starting is by compressed air (12 to 16 at. = 170.7 to 227.6 lb. per sq. inch) supplied by a four-stage compressor. The compressed air is cooled and oil is separated out between each stage. The fuel is supplied to each cylinder by a special piston pump driven from the main shaft, the fuel being introduced into the cylinder by compressed air at about 80 at. (1 140 lb. per sq. inch) pressure. The quantity of fuel can be regulated in 7 stages. The number of revolutions of the engine is controlled by an automatic centrifugal governor (maximum 8 r. p. s.). The pistons, cylinders, cylinder covers, exhaust pipes and exhaust manifold are cooled by water.

101. *The electric transmission.* — The generator has 12 poles with commutating poles, and is separately excited. The series motors are mounted in the manner of tramway motors and have 4 poles. The locomotive can be reversed by an electro-pneumatic controller which changes the direction of the current in the armature. Power is transmitted from the motor shaft by means of gear wheels to the driving axle, with reduction gearing in the ratio of 14 to 86. The efficiency of electric transmission falls off on gradients where the amperage is large and the voltage relatively small. In this case the efficiency falls to 75 or 80 %. It is higher at high speeds and with low tractive effort, attaining as much as 86 %.

102. *The cooling apparatus*, which serves to cool the water, has been rebuilt

TABLE 5.

Diesel locomotives.

—	*a*)	*b*)	*c*)
Engine number	001	005	...
Railway	Soviet Railways.	Soviet Railways.	Deutsche Reichsbahn.
Builder	Esslingen.	Hohenzollern.	Esslingen.
Axle arrangement	1 — A_3 — 1	2 — E — 1	2 — C — 2
Class of locomotive	Goods.	Goods.	Passenger.
Diesel engine:			
Maker	M. A. N.	M. A. N.	M. A. N.
Number of cylinders	6	6	6
Diameter of cylinders, in millimetres	450	450	450
Stroke, in millimetres	420	420	420
Maximum horse-power	1 200	1 200	1 200
Maximum revolutions per minute	450	450	450
Method of injecting fuel	Compressed air.	Compressed air.	Mechanical.
Transmission:			
Type of transmission	Electric.	Mechanical.	Pneumatic (1).
Capacity of generator, in kilowatts	800	...	...
Voltage of generator, in volts	600/1 000	...	...
Power of motor, H. P.	5 × 190	...	...
Compressor:			
Number of cylinders	...	...	2
Diameter of cylinders, in millimetres	...	..	640
Stroke, in millimetres	...	...	350
Pressure of compressed air, in atmospheres.	...	...	7
Temperature of superheat, in degrees centigrade	...	...	350
Diameter of driving wheels, in metres	1 220	1.320	1.600
Maximum speed, in kilometres per hour	50	54	...
Weight empty, in kilogrammes	114 000	124 000	...
Weight in working order, in kilogrammes.	119 000	131 000	...
Adhesive weight, in kilogrammes	90 000	88 000	...
Static tractive effort, in kilogrammes	15 000	17 500	...
Total length between buffers, in millimetres	13 820	16 695	15 800

(1) Water is injected to cool air.

several times. In principle, it has always been a surface radiator cooled by a current of atmospheric air. A similar radiator is used to cool the oil. Neither of the dimensions or the working of the original cooling apparatus were satisfactory. One of the two radiators originally carried on the engine was for this reason replaced by a larger radiator on the tender. The water flows through tubes through which the cooling air passes in an upward direction. The fans are driven by a special motor. Tests have also been made with a fin radiator of the M. A. N. type; the results however have not been entirely satisfactory.

103. *Tests.* — Numerous tests have been carried out both on a stationary test plant and also on the road in Germany and in Russia. The reports published by Professor Lomonosoff (see list at the end of this report) give full information.

The total maximum efficiency of the engine as observed during these tests was 24 to 26 %. In actual service, this efficiency may be taken as being about 20 %. For the consumption of fuel per 10 000 t.-km., see table 6.

B. — *4-10-2 Diesel locomotive with mechanical transmission, No. 005, of the Soviet Railways.*

104. *General arrangement.* — The position of the Diesel engine on the locomotive is the same as for the locomotive with electric transmission. The main magnetic clutch is fixed on a prolongation of the crank shaft and serves also as a fly-wheel. Beyond the main clutch is an elastic coupling which transmits the torque to a gear box with three gear ratios (1 : 7, 1 : 4, 1 : 2), and thence to a jack shaft which drives the coupled wheels in the usual manner. The radiators for oil and water are placed at the front of the locomotive. Near the front end is placed a four-stroke Diesel engine, without compressor, developing 45 H. P. at 1 000 r. p. m. This engine drives the radiator fan and the auxiliary electric generator, supplies current for the magnetic clutches and for lighting the locomotive and also drives an auxiliary air compressor for the brakes and whistle. If necessary, these auxiliaries can also be driven by the main engine. The auxiliary generator is connected to an auxiliary battery. The oil reservoirs are arranged on either side of the locomotive. A small steam boiler, which is heated, when running, by the exhaust gases, or alternatively by oil or wood, provides steam for carriage warming.

105. The M. A. N. *Diesel engine* has the same dimensions as that of the Russian locomotive with electric transmission; it is however reversible. Unlike the engine with electric transmission, the Diesel pistons are cooled by oil and not by water.

106. *Mechanical transmission.* — An important feature of the transmission is the electric-magnetic clutch constructed by Messrs. Magnetwerke of Eisenach. The extended shaft of the Diesel engine carries a magnetic head fitted with magnetising coils and which, due to its mass, acts as a fly-wheel. On the shaft of the gear box is a plate which, acting as an armature, is attracted to the magnetic head as soon as current passes. The armature has friction discs which allow the clutch to slip without overheating. A second elastic coupling transmits the torque to the gear box shaft. The intensity of the magnetising current can be regulated by introducing resistance into the circuit. In this way the pressure between the magnetic head and the armature may be in-

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with Diesel locomotive No. 001 with electric transmission and locomotive No. 005 w

Date of test.	Journey.	Length, in kilometres.	Weight of train, including locomotive.		Average running spe in kilometres per hour.	
			001	005	001	005
			Metr. tons.	Metr. tons.		
6/14 July 1927	Moscow-Baku (1).	2 392	887	871	28.9	30.(
17/24 July 1927	Baku-Moscow (1)	2 392	1 116	1 232	29.5	28.3

(1) Excluding section Prochladnaja to Gude

creased or decreased so that the train may be gradually started. Power is transmitted by the elastic coupling and by bevel wheels to the first shaft in the gear box, on which are mounted three spur wheels for the three gear ratios. These wheels mesh with corresponding wheels in the second shaft, which transmits the power by a special pair of wheels to the jack shaft. All the gear wheels are constantly in mesh and are brought into operation by means of magnetic clutches which are constructed on the same principle as the main clutch. If the current is interrupted, the armature is detached from the magnetic head by a spring. The gear box was made by Messrs. Krupp. In changing speed, one should momentarily disengage the main clutch. In this way the Diesel engine is disconnected from the driving wheels of the locomotive. To avoid breaking couplings, this time should be as short as possible, which depends largely upon the skill of the driver. The highest efficiency with this transmission (90 to 96 %) is obtained when exerting a large tractive effort at low speeds; at high speeds the efficiency is reduced to 80 %. The flexibility is appreciably less than for the Diesel engine with electric transmission or for a steam locomotive. The number of the speeds (3) is insufficient, and for Diesel goods locomotives, there should be at least four speeds. The plates of the main clutch are affected by the slipping of the wheels and heat up and wear rapidly.

107. *Cooling.* — The cooling water for the cylinders of the Diesel engine and for the compressor is circulated by a special pump [with a normal output of 48 m³ (1 695 cubic feet) per hour] driven from the main shaft of the engine. The water radiator is composed of ribbed pipes cooled on the outside by water. The total cooling surface is 530 m² (5 700 sq. feet). The current of air is induced by a Betz fan having a capacity of 130 000 m³ (4 590 000 cubic feet) per hour at 1 200 r. p. m. The power absorbed is about 60 H. P. The amount of air may be re-

LTS

echanical transmission of the Soviet Railways between Moscow and Baku, in both directions.

Average commercial speed of train, in kilometres per hour.		Work in 10 000 of tonne-kilometres.		Total fuel consumption.		Consumption of fuel, kilogrammes per 10 000 tonne-kilometres.	
001	005	001	005	001	005	001	005
				Kilogrammes.		Kilogrammes.	
16.5	20.1	211.9	206.4	9 569	8 663	45.2	42.9
19.3	18.2	267.0	294.7	10 097	9 862	37.8	33.5

here the locomotives ran over different lines.

gulated by closing the intake orifices in the side walls of the radiator. The oil radiator is placed in the front of the water radiator, so that the coldest air passes over it. It is made up of elements having a total cooling surface of 200 m² (2 150 sq. feet). After the Diesel engine has been stopped, a special electrically driven oil pump, driven from a battery of accumulators, comes into operation and continues to work for another 10 to 15 minutes to cool the pistons of the Diesel engine.

108. *Results of inspections and tests.* — The tests and their results are described in detail in the account published by Professor Lomonosoff. At normal speeds of 14 to 30 km. (8.7 to 18.6 miles) per hour, the overall efficiency of the locomotive ranges from 17 to 28 %, according to the degree of admission, that is to say, on the average at least three times as great as the best present day steam locomotive. The train hauled by the Diesel locomotive with mechanical transmission being about 5 % heavier, with a practically identical speed, the Diesel locomotive with mechanical transmission consumed about 10 % less fuel than the Diesel-electric. The actual oil consumption of the two Russian Diesel locomotives in service is shown in table 6.

C. — *4-6-4 Diesel locomotive with pneumatic transmission, Deutsche Reichsbahn.*

109. *General arrangement.* — This locomotive, which is intended for passenger traffic, is fitted with a M. A. N. Diesel engine of similar construction to those on the two Russian locomotives. A special two-cylinder double acting M. A. N. air compressor is direct coupled to the engine, which compresses air in one stage up to a pressure of 7 at. (100 lb. per sq. inch). With this arrangement, exterior cooling of the compressor by water is insufficient, and it is necessary to inject a certain amount of water (about 2 % of the weight of the air compressed) into the compressor. The mixture of air and

steam is superheated, as it passes towards the cylinders of the locomotive, to 350° or 370° C. (662 or 698° F.).

The result of superheating is that the air has a temperature of at least 80° C. (176° F.) after expansion, so that even in Winter no ice is formed in the cylinders. Superheating is by means of the exhaust gases from the Diesel engine. The mixture of air and steam is led through superheating pipes, around the outside of which the exhaust gases from the Diesel engine circulate. This type of superheater is very liable to deposits of soot and offers a large resistance to the flow of the exhaust gases, the more so since the velocity of this flow must be high (as much as 50 m. = 164 feet per second) in view of the low coefficient of heat transmission. The mixture of air and steam then expands in two simple expansion cylinders of ordinary type. After expanding, the mixture escapes to the atmosphere.

110. *Tests.* — The first tests carried out with this locomotive on a stationary test plant at the Esslingen Works have shown a total efficiency of 19 to 22 %. This engine is however only in the experimental stage. A detailed description of these tests have not been published up to the present.

* * *

111. The results obtained from tests and during actual working of high powered Diesel locomotives have shown a very high efficiency. However, this efficiency should not be directly compared with the efficiency of steam locomotives, for the price of 1 thermal unit from oil fuel is, as a general rule, higher than the cost of 1 thermal unit produced from coal. According to Professor Lomonosoff, the steam locomotive is more economical, both where the price of oil is exceptionally high, and also where it is exceptionally low, if in the first place it burns coal and in the second place it burns oil. In view of the present day ratio between the price of coal and oil, a number of writers consider that the Diesel engine is the more economical, even if not only the cost of fuel, but also the total cost of lubrication and working expenses are taken into account. This is partly due to certain advantages offered by the Diesel engine, such as time saved in raising steam and in getting coal and water, so that their average daily mileage may be higher than that of the steam locomotive. Mr. Strasser, in the *Organ für Fortschritte im Eisenbahnwesen*, 1929, p. 123, has compared the total cost of the three large Diesel engines mentioned above, with that of the steam locomotive of present day type. The results he gives are as follows :

	Total expediture in Reichmarks per 1000 locomotive kilomètres (621 locomotive-miles).	Economy in %.
Steam locomotive . . .	2 026	—
Russian Diesel locomotive with electric transmission	1 695	16.5
Russian Diesel locomotive with mechanical transmission	1 611	20.5
German Diesel locomotive with pneumatic transmission (1) . .	1 775	12.5

It may be noted that he assumed a daily run of 300 km. (186 miles) for the steam locomotive and 400 km. (250 mi-

(1) This refers to a Diesel goods locomotive with pneumatic transmission similar to the passenger locomotive mentioned above.

les) for the Diesel locomotives. Although admittedly these figures are large based on estimates which must be borne out in practice, it will be seen that the saving is appreciable. The actual cost of the Diesel locomotives is of course much higher than for the steam locomotive, being at least 80 to 100 % more with the Diesel locomotive with electric transmission, and 40 to 50 % more for the locomotives with mechanical or pneumatic transmission.

In spite of the economy shown by tests, the construction of Diesel locomotives has not yet reached the point where one can hope for a rapid extension of their use, except in special cases, as for example, in countries where there is a lack of water. The Diesel locomotives constructed up to the present may be regarded, in the opinion of their eminent designer, Professor Lomonosoff « as laboratories on wheels »; these are experimental locomotives which should prepare the way for ultimate developments. There is no doubt that in the future the Diesel locomotive will be one of the main objects of experimental work, especially when a solution has been found to the problem of producing liquid fuel from coal.

CONCLUSIONS.

112. In spite of the great efforts which have been made in different countries, up to the present no definite new type of locomotive has been perfected. We are still in a period of researches, preliminary work and tests. Already various experimental locomotive have been built with an efficiency considerably greater than that of steam locomotives of the normal type. This improvement has so far been obtained, in the majority of cases, at the price of a more complicated construction less suitable for conditions of service on the railways, this being the case both for condensing locomotives and for Diesel locomotives. The most promising method of increasing the economy of locomotives, while maintaining the valuable properties of the existing type, appears to lie in the high pressure non-condensing type, as for example, the Winterthur locomotive. Obviously, however, even in this respect, there are still some essential difficulties to overcome.

Already the efforts made to construct a new type have been valuable in having the effect of opening up new lines of development of the locomotive, which still remains the most important method of mechanical transport.

The path towards a new type of locomotive would be greatly aided if there existed in Europe a scientific test plant suitably equipped for carrying out tests on locomotives to supplement practical tests already carried out by most railway administrations by means of dynamometer cars. It might perhaps be possible for the Railway Congress to put forward a resolution that the European railway administrations affiliated to this Association should direct their attention to this question.

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REPORT No. 5

(Germany)

ON THE QUESTION OF ELECTRIC LOCOMOTIVES FOR MAIN LINE TRACTION (SUBJECT VII FOR DISCUSSION AT THE ELEVENTH SESSION OF THE INTERNATIONAL RAILWAY CONGRESS ASSOCIATION) (1) (2),

by Dr.-Ing. WILHELM WECHMANN,
Reichsbahndirector and Member of the Headquarters Administration of the Deutsche Reichsbahn Gesellschaft (German State Railway Company).

Figs 1 to 34, pp. 1312 to 1344.

SUMMARY OF CONTENTS.

1. General lines followed in the design.
2. Parts of standard design.
3. Short description of some of the latest electric locomotives.
4. Drive.
5. Measurement of vibration in the driving mechanism.
6. The single-phase series railway motor.
7. Air-break main switch.
8. Control with fine regulation.
9. Interlocking of control and brakes.
10. Dead man's handle and safety gear.
11. Electric braking.

1. — General lines followed in the design.

The Deutsche Reichsbahn Gesellschaft (German State Railway Company) employs single-phase low frequency current for main line traffic. The designed voltage of the trolley wire is 15 kilovolts and the frequency 16-2/3 hertz or periods per second.

The permissible voltage variation is between 16.5 and 12 kilovolts and, for short periods, down to 11 kilovolts. The frequency may vary between 17 1/2 and 15 periods.

The upper limit of voltage corresponds approximately to no-load conditions at the bus bars of the sub-station. A minimum value had to be fixed, because various electro-magnetic apparatus on the locomotives and rail motor coaches would become inoperative below a certain voltage. In order to secure reliability of operation the Reichsbahn specifies that electro-magnetic apparatus must be capable of operating effectively at 10.5 kilovolts.

The current entering the locomotive from the overhead conductor through the bow is led into the high tension winding of the main transformer. On the low tension side the transformer has a certain number of tappings for different voltages. By means of the control gear the motors may be supplied with current at different voltages according to require-

(1) This question runs as follows: « *Electric locomotives far main line traction : a*) passenger locomotives; *b*) goods locomotives; *c*) locomotives for mountainous country. Multiple unit traction. »

(2) Translated from the German.

ments for starting and running conditions. All the motors are of the *series-commutator type.*

The general arrangement is the same for all electric locomotives of the Reichsbahn except for one type of shunting engine, the construction of which will be briefly dealt with later on.

Neither convertor locomotives nor locomotives with phase-splitting devices are in operation. Similarly the Reichsbahn has hitherto avoided the use of alternating current motors without commutators, such as have during the last few years proved their utility on certain special railways as for instance in mines.

The use of single-phase current, carried right into the motors, leads to a design of locomotive which is as simple and accessible as possible in all its parts and tends to make for a relatively low weight. It is true that a low frequency must be accepted as part of the bargain and this necessitates the erection of special generators at the power stations or alternatively that the standard three-phase current used for general distribution at a frequency of 50 periods, which is common in Germany, must be converted either at the power station or in the sub-stations to traction current at the lower frequency.

From the workshop point of view a locomotive of great simplicity in construction is undoubtedly desirable. The regular inspection and repair work on the locomotives can be carried out in the shortest time with the help of comparatively simple machine tools and hand gear.

It is true that the simplicity of construction may for instance lead to a reduction in the efficiency of the transmission of energy in the locomotive itself or the phase displacement resulting from the electrical conditions in the locomotive may not be fully satisfactory; but the criterion for the value of the locomotive is the total cost incurred, that is the sum of the costs made up principally of energy consumption, service, attendance and maintenance.

2. — Parts of standard design.

During the last 10 years, experience covering a large range of conditions was obtained regarding the behaviour and lasting quality of electric locomotives and of the individual parts which go to make them up.

For this reason a definite decision regarding the most suitable design of certain parts could be arrived at. This resulted in the standardization of design of such parts. Among these may be mentioned :

The main switch (oil switch) (1);

The current collector and the arrangements in the driver's compartment for operating same (2);

The electrically-driven air pump;

The measuring instruments, the marking and figures on the dials of the latter and their disposal in the driver's cabin (3);

The continuous current lighting installation and various safety devices (4);

The parts required for working the electric heating of the train (5);

Various switches and other small gear.

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(1) *Elektrische Bahnen*, 1925, p. 332.

(2) *Elektrische Bahnen*, 1927, p. 105.

(3) *Elektrische Bahnen*, 1926, p. 233.

(4) *Zentralblatt für den Elektrischen Zugbetrieb*, 1928, p. 118.

(5) *Elektrische Bahnen*, 1926, p. 421; 1927, p. 92; 1929, pp. 166 and 216.

The advantages of uniformity are obvious. Standardization of the design of parts materially facilitates their operation, attendance and maintenance; the parts can be manufactured in quantities; the number of spares is reduced to a minimum.

In this connection mention may be made specially of the inscriptions on the dials of current meters and speed recorders, as they have been standardized by the Deutsche Reichsbahn.

On the dials of the current meters, which indicate the current taken by individual motors, this intensity in amperes is not marked, but the units corresponding to the tractive effort of the motor, measured in tons at the tread of the driving wheel, which effort is approximately proportional to the intensity of the current. The reason for this is that the instrument then indicates units which are directly comparable for all classes of locomotives. On the other hand the amount of current taken by the motor depends on the tension at the motor; hence it will vary for different types of locomotive. Further, the driver has a much better idea of the tractive effort, which is required for starting up, mounting a gradient, or running at a certain speed, for any given weight of train than of the amount of current required.

The speed indicators, in addition to the speed scale, are provided with a second scale which indicates for each speed the permissible tractive effort (see fig. 1).

The driver is able to work within the permisible loads for his locomotive by observing the instrument indicating the tractive effort and that indicating the speed.

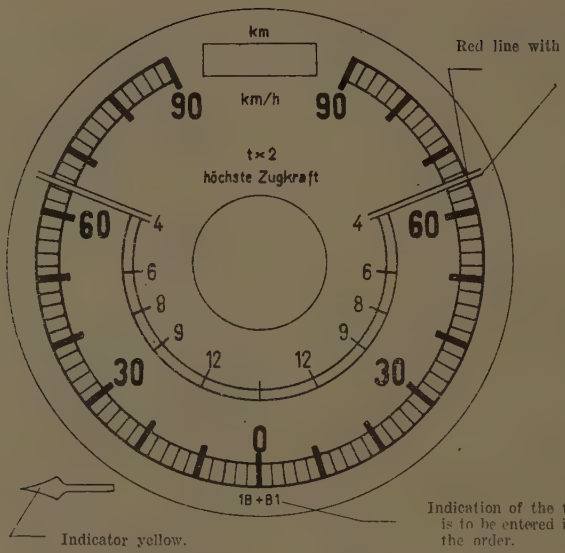
The calculation of the indications for the tractive effort have hitherto been based on the efficiency curve (efficiency as a function of the speed) of the particular locomotive.

The values shown on the speed indicators represent, in accordance with the efficiency curve, *starting tractive efforts* for speeds from zero to 25 % of the maximum speed, from 25 % to 55 % of the maximum speed at the *one-hour rating* and for the remaining range of speeds they represent the tractive efforts for *continuous rating*.

On account of the variations in the heating characteristics of motors and because the average loading of the locomotives and hence also the heating of the driving motors and transformers are affected to a varying degree according to the service which the locomotive is called upon to perform, the Reichsbahn decided to mark on the speed indicators the maximum tractive efforts, which are obtained by tests on the line. These indications for tractive effort are not referred as hitherto to the heating limit but to the commutation limits for driving motors and the figures may therefore not be exceeded when accelerating or in any other circumstances under which the locomotive may be subjected to severe stresses.

The general use of standardized parts is not allowed to stand in the way of progress in design from the engineering point of view. On the contrary important innovations are studied and if they appear suitable for the locomotives, trials are made to test them out. In this connection may be mentioned the developments in main switch design, particularly the oil-less type. This is reported on later in section 7.

Other parts of the electric locomotive, and especially the principal parts, namely, the transformer, control apparatus and motor have not yet arrived at a stage



Remark: The dials are marked with *white* figures on *black background*. The dial shown serves as an *example* for 1B + B1 locomotives. t × 2 höchste Zugkraft = t × 2 maximum tractive power.

Fig. 1. — Dial for speed gauge.

when standardization is possible. Different types of locomotives are therefore equipped with these parts of varying designs.

Efforts are being made to introduce air cooled transformers throughout, as it is undesirable to carry oil on a railway vehicle. The air cooled transformers which have been supplied during the last years meet most of the requirements, except that the method of using the cooling air could possibly be improved.

The *motor control gear* is likewise supplied in different designs, namely, both controllers of the relay-operated contactor type and of the sliding contact type are used and the control with fine regulation, further details of which will be given in section 8.

3. — Short description of some of the latest electric locomotives.

In order that the terms which are used to indicate different designs of locomotive should be clearly understood a short explanation of the methods adopted for describing them is given.

Classification.

The electric locomotives are divided into classes or types. Each class has a type mark. This is made up of the letter E (electric) and a basic number composed of two figures.

The numbers are reserved as follows :

01 to 29 for locomotives with a maximum speed of over 90 km. per hour;

30 to 59 for locomotives with a maximum speed of 70 to 90 km. per hour;

60 to 99 for locomotives with a maximum speed under 70 km. per hour.

The *service number* of the locomotive consists of the class mark and, separated by a short space, the serial number of the locomotive, which latter may have 2 or 3 figures.

For example, if a locomotive is marked E 17 13 this means that it is an electric locomotive having a maximum speed exceeding 90 km. per hour and being built to a particular design and that it is No. 13 of that class of locomotive (1).

The sequence of the axles (leading, trailing and driving wheels) is indicated in the same way as for steam locomotives in accordance with the regulations of the Association of German Railway Administrations.

If the electric locomotive is provided with individually driven driving axles, a small *o* is placed after the capital letter which indicates the number of driving axles carried in one train. Thus 1 Co + Co 1 indicates a locomotive consisting of two sections coupled together, each section having a carrying axle at the free end, followed by 3 independently driven driving axles (2).

Among the electric locomotives supplied to the Reichsbahn in recent years certain types are only represented by one or two engines, whereas of other types complete series are in existence.

The former types served or serve as experimental locomotives for the development of the type for a series.

Thus the express locomotive 2 Do 1 (Class E 21) was first of all evolved as an experiment. This was later on modified for manufacture in numbers to form Class E 17 with axles 1 Do 1. At the present time two express locomotives are being tried out, the arrangements of which are respectively 1 Bo + Bo 1 and 1 Do 1 (see section 4). Whether either of these two engines will become the precursor of a new class of which a series will be constructed, has not yet been decided.

One of the principal characteristics of the newer types of locomotive is the different method of drive. Some classes of locomotive are arranged for group drive, others for the individual driving of each axle.

Table 1 gives details.

Table 2 contains the leading particulars regarding the design and the operating values of the locomotives. These locomotives are described in detail in the literature referred to in the last line of the table. It should therefore suffice at this juncture to draw attention to a few specially important characteristics of the different types of locomotive.

Express locomotive type E 06 (fig. 2) is designed for running in flat country. The scheduled train loads are for express trains, 600 tons, for ordinary trains, 500 tons.

The locomotive has only one driving motor. It is the largest railway motor made in one unit. It is cooled by means of two fans mounted on the motor.

The first five engines of this type (the first order) were fitted with oil cooled transformers and special oil coolers and blowers; the 7 locomotives ordered later were fitted with air cooled transformers.

(1) For more details see *Elektrische Bahnen*, 1927, p. 241.

(2) *Association (Verein) of German Railway Administrations*, Committee on Technical Matters, Special Committee on Design and Operation of Electric Railways, Report No. 4, 1925.

TABLE 1

New Reichsbahn locomotives classified according to axle drives.

A. — *Locomotives with connecting rod drive.*

Drive.	Number.	Class.	Axle arrangement.	Maximum speed, kilometres per hour.
Simple connecting rod drive.	12	E 06	2 C 2	110
Connecting rods with gear wheels.	27	E 75	1 BB 1	65
Connecting rods with gear wheels.	46	E 91	C + C	55
Connecting rods with gear wheels.	7	E 60	1 C	55
Connecting rods with gear wheels.	29	E 32	1 C 1	75

B. — *Locomotives with individual axle drive.*

Driving pins, Buchli type .	17	E 16	1 Do 1	110
Quill drive, Westinghouse-Kleinow type.	2	E 21	2 Do 1	110
Quill drive, Westinghouse-Kleinow type.	38	E 17	1 Do 1	110
Simple gear wheel drive with axle-supported motor.	6	E 95	1 Co + Co 1	65
Simple gear wheel drive with axle-supported motor.	1	E 18	1 Bo + Bo 1	110
Simple gear wheel drive with axle-supported motor.	1	E 16	1 Do 1	110
Simple gear wheel drive with axle-supported motor.	5 with rectifiers and accumulators.	E 80	A1A + A1A	40

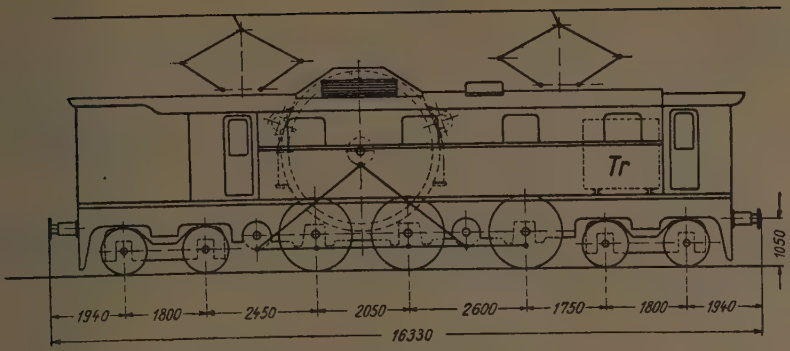


Fig. 2. — Express locomotive for flat country, Class E 06.

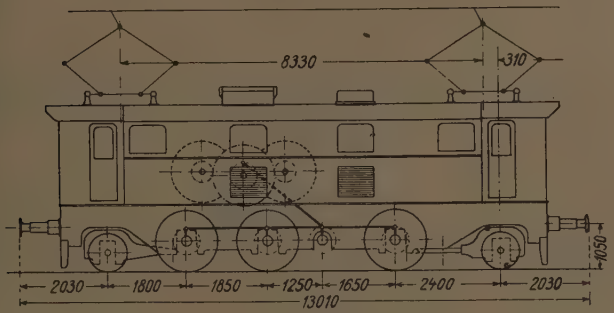


Fig. 3. — Small locomotive for ordinary passenger trains, Class E 32.

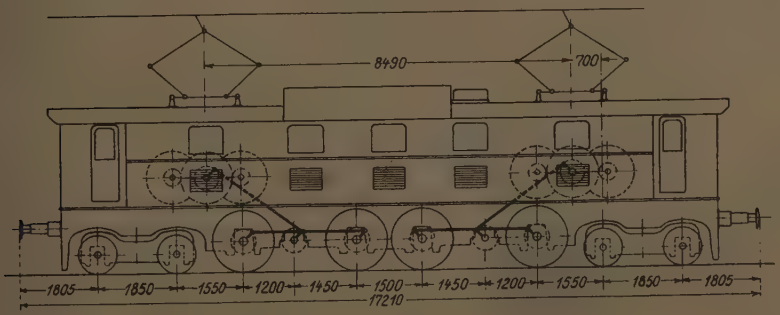


Fig. 4. — Heavy locomotive for ordinary passenger trains, Class E 52.

Designation. / Axle sequence. / Class.	LOCOMOTIVES WITH CONNECTING A			
	Express locomotive. 2 C 2. E o 6.	Locomotive for stopping passenger trains. 1 C 1. E 32.	Locomotive for stopping passenger trains. 2 BB 2. E 52.	Goods locomotiv 1 BB 1. E 75.
Maximum speed . . . . . km. per hour	110	75	90	65
Maximum tractive effort measured at the tread of driving wheel . . . . . kgr.	18 700	11 000	22 700	22 400
Referred to time period of . . . . . seconds	10	60	60	10
Nominal power (measured at the motor shaft and according to heating specifications of I. R. U.) . . . . . kw.	2 160	1 150	2 250	1 730
At speed of . . . . . km.	62	61	62.5	52
Number of motors	1	1 double motor.	2 double motors.	2
Type of power transmission	Triangular connecting rod with 2 lay shafts.	Gear wheels, connecting and coupling rod.	Gear wheels, connecting and coupling rod.	Gear whe and inclin rods.
Gear ratios.	...	1 : 3.27.	1 : 2.866	1 : 2.61
Type of control	Electro-pneumatic relay contactors.	Sliding contact control.	Electro-magnetic relay contactors.	Fine regula
Weight of electrical gear . . . . . m. tons	38.0	31.2	69.7	55.4
Weight of mechanical gear . . . . . m. tons	71.5	53.6	70.3	51.6
Total weight . . . . . m. tons	109.5	84.8	140.0	107.0
Adhesion weight . . . . . m. tons	56.4	56.4	78.0	76.0
Maximum load on driving axles . . . m. tons	18.8	18.8	19.5	19.0
Maximum load on carrying axles . . . m. tons	13.4	15.4	15.5	15.4
Diameter at tread of wheels (when new): Driving . . . . . mm.	1 600	1 400	1 400	1 400
Carrying . . . . . mm.	1 000	850	850	1 000
Length over buffers . . . . . mm.	16 330	13 010	17 210	15 380
Total wheelbase . . . . . mm.	12 450	8 950	13 600	11 200
Rigid wheel base . . . . . mm.	4 650	1 850	...	5 300
Weight per kilowatt of nominal power (indicated above) . . . . . kgr.	50.7	73.8	62.3	61.8

TABLE 2.

UPLING ROD DRIVE.		LOCOMOTIVES WITH INDIVIDUAL AXLE DRIVE.				
Goods locomotive.	Shunting locomotive.	Express locomotive.	Express locomotive.	Express locomotive.	Goods locomotive.	Shunting locomotive.
C + C. E 91.	1 C. E 60.	1 Do 1. E 16.	1 Do 1. E 17.	1 Bo + Bo 1. E 18.	1 Co + Co 1. E 95.	A 1 A + A 1 A. E. 80.
55	55	110	110	110	65	40
27 000	18 000	21 000	24 000	20 900	36 000	13 000
10	10	60	60	10	60	60
2 080	1 090	2 520	2 800	2 530	2 715	276
41	38.8	82	89	88	49	13.3
uble motors.	1 double motor.	4	4 double motors.	4	6	4
ear wheels nd inclined rods.	Gear wheels and inclined rods.	Gear wheels, Buchli drive.	Westinghouse quill drive.	Gear wheels, motors axle supported.	Gear wheels, motors axle supported.	Motors mounted on the axle.
1 : 4.04.	1 : 4.04.	1 : 2.63.	1 : 5.11.	1 : 3.65.	1 : 5.294.	1 : 5.94.
ctro - magne- c relay con- actors.	Electro - magnetic relay contactors.	Sliding contact control.	Electro - magnetic relay contactors.	Electro - magnetic relay contactors.	Electro - magnetic relay contactors.	Servo-motor with drum.
57.9	38.6	52.7	46.3	48.4	64.4	50.0
58.5	34.0	56.8	63.7	55.8	73.9	44.7
116.4	72.6	109.5	110.0	104.2	138.3	94.7
116.4	58.3	79.0	80.0	73.6	115.8	70.0
19.5	19.5	19.75	20.0	18.4	19.3	17.5
...	14.3	15.25	15.0	15.0	11.5	12.5
1 250	1 250	1 640	1 600	1 400	1 400	1 000
...	850	1 000	1 000	1 000	850	1 000
17 300	11 100	16 300	15 950	16 836	20 900	15 400
12 460	6 600	12 600	12 300	13 800	17 600	11 300
4 700	4 500	...	...	3 400	4 600	...
56.0	66.6	43.5	39.3	41.2	50.9	343 (including battery).

Designation. Axle sequence. Class.	LOCOMOTIVES WITH CONNECTING A			
	Express locomotive. 2 C 2. E o 6.	Locomotive for stopping passenger trains. 1 C 1. E 32.	Locomotive for stopping passenger trains. 2 BB 2. E 52.	Goods locomotive 1 BB 1. E 75.
Manufacturer of electrical portion	Bergmann-Elektricitäts-Werke Co., Berlin.	Brown, Boveri & Co., Mannheim-Käfertal.	Allgemeine Elektricitäts-Gesellschaft, Berlin, and Siemens-Schuckertwerke Co., Berlin.	Bergmann-El tricitäts-Wer Co., Berli and Maffe Schwartzkop Werke, Ber
Manufacturer of mechanical portion	Berliner Maschinenbau Co., formerly L. Schwartzkopff, Berlin.	J. A. Maffei Co. Munich.	J. A. Maffei Co., Munich.	Linke-Hofm Busch-Wer Berlin.
Bibliography	Elektrische Bahnen 1928. Pp. 291 to 297.	Elektrische Bahnen 1925. Pp. 181 to 194.	Elektrische Bahnen 1926. Pp. 241 to 262.	...

The cooling air is drawn through the transformer by means of a motor driven exhauster. These 7 locomotives are provided with air filters which are kept oily for cleaning the cooling air.

The control is effected by means of electrically controlled pneumatic contactor relays. The output of the motor can be increased beyond the last control stage by displacing the brushes.

Small passenger locomotive (for stopping trains), class E 32 (fig. 3) can start up a train of 300 tons on a one per cent gradient on a straight or slightly curved road and is capable of accelerating up to 25 km. (16.5 miles) in 70 seconds.

The double motor has two sets of 12 poles and commutating poles with shunt resistance. Resistances are inserted between the commutator and the rotor windings.

Passenger locomotive (for stopping trains), class E 52 (fig. 4), is employed for working trains up to 500 tons in weight in mountainous country.

At the time, this locomotive was particularly carefully worked out. It is very reliable, but is not likely to be repeated in the future on account of its great weight in relation to the output of the motors.

Small goods locomotive of classes E 75 and E 77 (E 75 in fig. 5) are designed for working goods trains, on the flat, of up to 1 500 tons in weight at a speed of 60 km. (37.3 miles) per hour.

TABLE 2 (*continued*).

UPLING ROD DRIVE.		LOCOMOTIVES WITH INDIVIDUAL AXLE DRIVE.				
Goods locomotive.	Shunting locomotive.	Express locomotive.	Express locomotive.	Express locomotive.	Goods locomotive.	Shunting locomotive.
C + C. E 91.	1 C. E 60.	1 Do 1. E 16.	1 Do 1. E 17.	1 Bo + Bo 1. E 18.	1 Co + Co 1. E 95.	A 1 A + A 1 A. E. 80.
llgemeine ektricitäts-esellschaft, lin, and Sie-s Schuckert-verke Co., Berlin.	Allgemeine Elektricitäts-Gesellschaft, Berlin.	Brown, Boveri & Co., Mannheim-Käfertal.	Allgemeine Elektricitäts-Gesellschaft, Berlin, and Siemens-Schuckertwerke Co., Berlin.	Siemens-Schuckertwerke Co., Berlin.	Allgemeine Elektricitäts-Gesellschaft, Berlin, and Siemens-Schuckertwerke Co., Berlin.	Siemens-Schuckertwerke Co., Berlin.
—	—	—	—	—	—	—
llgemeine ektricitäts-esellschaft, Berlin.	Allgemeine Elektricitäts-Gesellschaft, Berlin.	Lokomotiv-fabrik Krauss & Co., Munich.	Allgemeine Elektricitäts-Gesellschaft, Berlin.	A. Borsig, Co. Ltd., Berlin-Tegel.	Allgemeine Elektricitäts-Gesellschaft, Berlin.	J. A. Maffei Co., Munich.
lektrische hnen 1925. 311 to 320 d Elektro-urnal 1924, 257 to 265.	Elektrische Bahnen 1928. Pp. 309 to 313.	Elektrische Bahnen 1927. Pp. 71 to 92.	...	Elektrische Bahnen 1928. Pp. 2 to 12.	Elektrische Bahnen 1929, Special issue, « Fünfzig Jahre Elektrische Lokomotive ». Pp. 4 to 19.	...

Each of the two driving motors has 20 poles, compensating winding and commutating poles with shunt resistance.

The locomotives supplied earlier had articulated frames (class E 77, type 1 B + B 1), while the later ones had a continuous frame (class E 75, type 1 B B 1).

Heavy goods engines of class E 91 (fig. 6) are designed for hauling goods trains of up to 1 400 tons in mountainous country.

The transformer is oil cooled. The oil is pumped through the transformer by means of pipes with fins which are cooled in their turn by a fan. The two double motors have two sets of 10 poles. Rheostatic braking was supplied with the last lot of locomotives ordered (see section 11).

The connecting rod drive is, from a purely dynamic point of view, not entirely satisfactory, because the lay shaft is placed at a higher level than the driving axle. Nevertheless no defects have been noticeable in actual operation.

Small goods engine of class E 60 (fig. 7) are fitted with the same motors and the same drive as detailed for locomotive class E 91, mentioned above.

Express locomotive of class E 16 (fig. 8) is used in mountainous country. It starts with a load of 650 tons on a one per cent gradient, on a straight or slightly curved track with ease, accelerates to 55 km. (34.2 miles) in 6 1/2 minutes and runs over the above-mentioned gradient at 70 km. (43.5 miles) per hour.

The 4 driving motors are 12-pole, com-

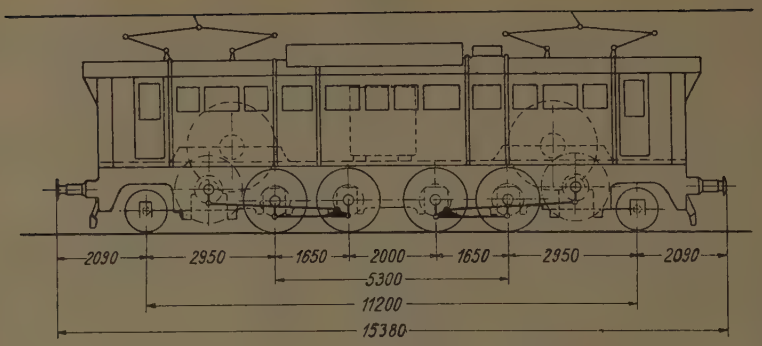


Fig. 5. — Goods train locomotive, Class E 75.

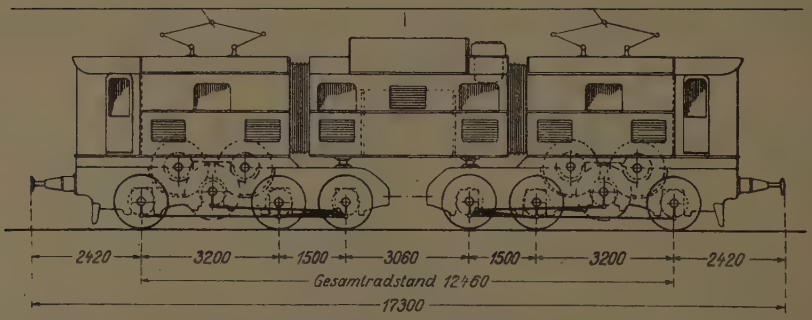


Fig. 6. — Heavy goods train locomotive, Class E 91.

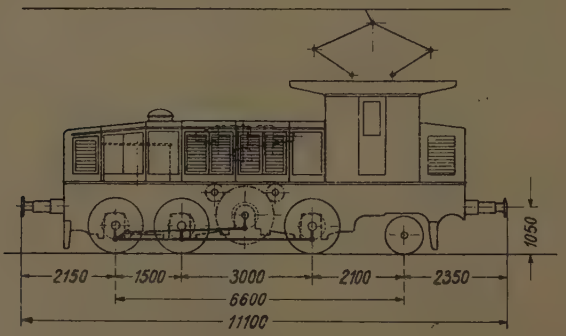


Fig. 7. — Small goods train and shunting locomotive, Class E 60.

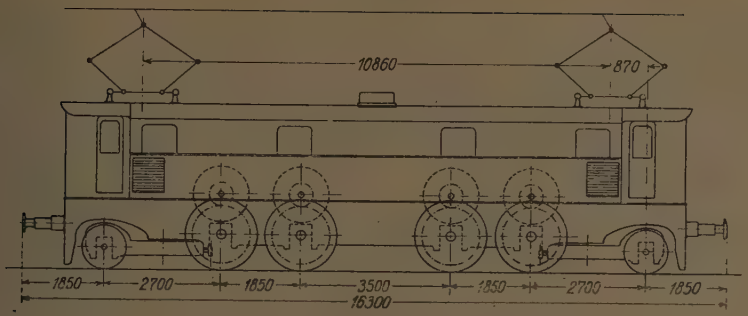


Fig. 8. — Heavy express locomotive, Class E 16 (Buchli drive).

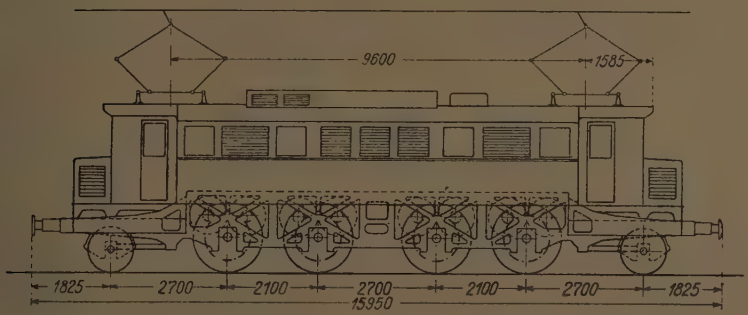


Fig. 9. — Heavy express locomotive, Class E 17 (Westinghouse-Kleinow drive).

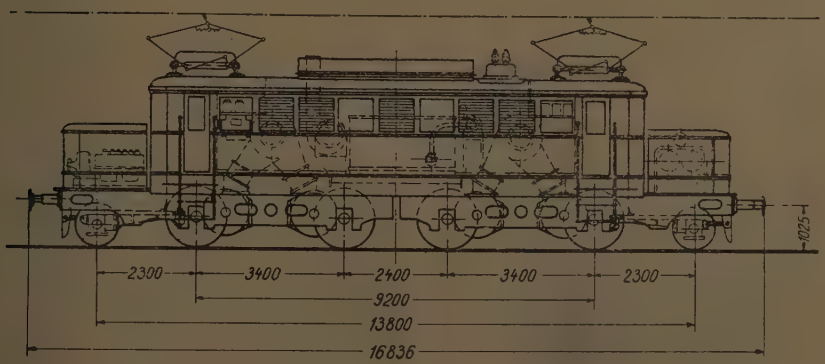


Fig. 10. — Heavy express locomotive, Class E 18, with axle supported motors.

pensated series, with resistances between the commutator and rotor windings; they are fitted with commutating poles with shunt resistance. The driving axles are driven individually by means of Buchli gears.

The express locomotive class E 17 (fig. 9) differs from the previous one in that each of its 4 driving axles is individually driven by a double motor through a quill drive.

Further, in order to minimise the consumption of lubricating oil in the driving axle boxes, axle boxes of the « Isothermos » system are used. The construction of the Isothermos axle boxes may be assumed to be known. The success of these arrangements is shown by the following figures.

Oil consumption of a locomotive :

With standard axle boxes 2 to 2.5 kgr. per 1 000 locomotive-km. (8.87 lb. per 1 000 locomotive-miles).

With « Isothermos » axle boxes 0.1 kgr. per 1 000 locomotive-km. (0.355 lb. per 1 000 locomotive-miles).

It is intended for future orders to provide the free axles as well with suitable oil-saving axle boxes.

This locomotive will draw a train load of 520 tons on a 2 per cent gradient. On a one per cent gradient and on curves of 180 m. (9 chains) radius a load of 700 tons is handled.

The express locomotive, class E 18, type 1 Bo + Bo 1 (fig. 10) is an experimental locomotive of which only one was ordered; a second, having the same electrical system but with a continuous frame (type 1 Do 1) was also purchased.

The train loads for these express trains are of 600 tons in Summer and 630 tons in Winter, with an average running speed of 100 km. (62 miles) per hour and for ordinary passenger trains, 500 tons in Summer and 530 tons in Winter, with an average running speed of 75 km. (46.6 miles) per hour and a commercial speed of 45 km. (28 miles) per hour.

The transformer is oil cooled. The oil is circulated through cooling pipes with fins which are themselves cooled by suction fans.

The locomotive is the first high speed locomotive of the Reichsbahn having axle-supported motors.

Each bogie frame carries two driving motors, which are supported at one end by bearings cast on to the frame of the motor and fitted on the driving axles and, at the other end, are suspended from the bogie frame by means of 2 bolts and spiral springs.

The heavy goods locomotive, class E 95 (fig. 11) is the most efficient of all the Reichsbahn goods locomotives.

On trial runs the results were as follows :

A goods train of 1 409 tons was drawn over the route *Hirschberg-Schlauroth* and back where the ruling gradient is one per cent;

A goods train of 2 568 tons was taken over the route *Königszelt-Breslau* and back.

The six motors have eight poles and are supported on the axles and suspended from the frame in a similar way to the E 18.

Shuntig locomotives with rectifiers.

As already stated in section 1, the Reichsbahn possesses special locomotives, used for shunting, which are not designed as single phase motor locomotives.

At important regulating stations there are tracks and groups of tracks which are never used by arriving and departing

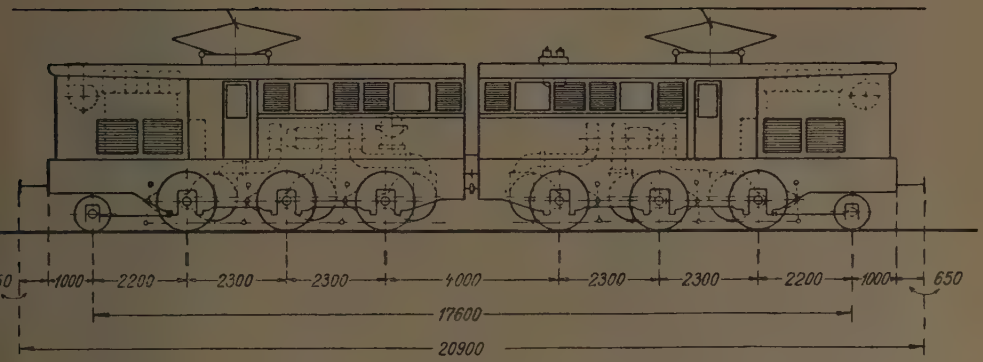


Fig. 11. — Heaviest goods train locomotive of the Reichsbahn, Class E 95. with axle supported motors.

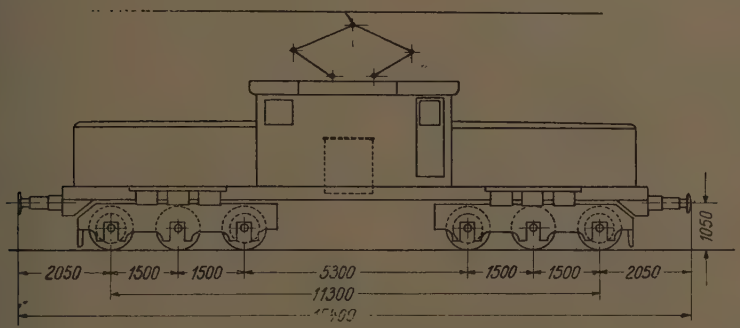


Fig. 12. — Shunting locomotive with rectifier, Class E 80.

trains and only rarely used by trains which are being made up. An overhead conductor would be wasted over such tracks. On certain tracks, for instance where loading goes on, it is very undesirable to have a trolley wire with its high electric pressure. These conditions induced the Reichsbahn to try out a few shunting engines which, besides being arranged to take energy from the overhead wire, had also available a source of supply on the locomotive itself. These shunting engines (fig. 12) have two mercury arc rectifiers each of 300 amperes capacity and a battery of 780 ampere-hours at a discharge rate of 78 amperes. The battery is charged automatically by the rectifier. The locomotive has 4 motors each of 62 kw. on an hourly rating; the tractive effort measured at the tread of the

wheels amounts to 13 tons between zero and 7 km. (4.35 miles) per hour; maximum speed 40 km. (25 miles) per hour.

The connections are arranged so that current may be taken from the rectifier only, from the battery only or from both at the same time.

These engines have not been in service long enough to allow of definite conclusions being reached. There is however no reason to expect trouble, as the same type of rectifier has been in use for some time on the tower wagons of the railway, for overhead line repair work (1).

The following notes contain remarks on component parts of the alternating current locomotives of the Reichsbahn and some account of their behaviour in service.

4. — Drive.

Up to about 1925 the Reichsbahn had favoured coupled driving axles, that is a group drive, because by this method slipping of individual pairs of drivers is avoided and thereby the maximum adhesion is secured. The axles are coupled by rods. Examples of efficient locomotives with coupling rods are given in table 2.

These designs comply with the requirements for safety and reliability in operation.

Nevertheless the Reichsbahn have in the last years tended more and more to the adoption of the *individual axle drive*, both for fast passenger and goods trains. The doubts which were formerly raised, that the adhesive weight would not be so well used in the latter type as in the former, have not been justified under service conditions. It is true that care must be taken by suitable mechanical and electrical arrangements to avoid conditions which would favour slipping of an isolated pair of wheels. Should a pair of drivers start slipping on a greasy rail, means must be provided that the motor cannot run away. One method of preventing this is to connect all the motors permanently in parallel. This is easily arranged with alternating current and has been generally adopted by the Reichsbahn (1).

In addition to the reduced wear on the bearings, the individual axle drive has a further advantage in that damaged motors can be changed at the repair shops by means of relatively simple arrangements and in a very short time.

The individual axle drives adopted for the Reichsbahn locomotives are the pin drive, Buchli type; the spring drive by means of a quill, Westinghouse Kleinow type, and the direct gear wheel drive with motors with spring suspension at one end and supported by the driving axle itself at the other.

The Buchli drive has been frequently described and is therefore fairly well known (2).

This drive works very well in service and is noted for the fact that it requires extraordinarily little repair work (3).

In the hitherto most usual form with one pair of gear wheels outside the running wheels it is only suitable for high speed locomotives, as in such cases the gear ratio cannot exceed a certain limit, for example with a driving wheel of 1.640 m. (5 ft. 4 9/16 in.) diameter the ratio can hardly exceed 1 : 2.6.

This restriction disappears if an intermediate gear is introduced between the

(1) *Elektrische Bahnen*, 1928, pp. 69 et seq.

(1) See also measurements taken by A. E. Müller in Switzerland. *Schweiz. Tech. Zeitung*, 1928, p. 745, and *Elektrische Bahnen*, 1928, pp. 63 and 192.

(2) *Elektrische Bahnen*, 1927, p. 73; V. D. I., 1929, pp. 683 et seq.

(3) *Elektrische Bahnen*, 1929, p. 103.

motor shafts and the spur wheel coupled to the driving wheel. Such an arrangement does not obtain in the Reichsbahn locomotives; also hitherto only one motor for one driving axle has been employed with the Buchli drive. There is however no reason why several driving axles should not be coupled together by gear wheels and why this system should not be driven by several motors; in this case the number of motors may be less than the number of driving axles. It is true that the principle of single axle drive would thus be departed from.

In table 3 several classes of locomotives are indicated with a view to studying the conditions which led to development in this direction. The classes 1 to 6 referred to are satisfactory with one motor having an output at the hourly rating of about 700 kw.

In the types indicated in table 3 under 7 to 9, a double motor is assumed, rated at 425 kw. on the hourly rating. In this case (see fig. 13) the pinions engage a spur wheel which is common to both and is arranged inside the driving wheels and is carried on a hollow stub shaft.

This arrangement is therefore in contrast to the practice adopted hitherto in the Buchli drive, where the gear wheels are carried outside the wheels. The new arrangement of drive permits a straight individual gear drive for higher gear ratios than has hitherto been the practice, and without the adoption of additional gear wheels.

The second type of individual axle drive carried out for the Reichsbahn is, as stated above, the Westinghouse-Kleinow quill drive. This has likewise been described in a number of articles (1).

The principal point of the Kleinow design is that the springs are mounted in and guided by dashpot cylinders. The guiding prevents the springs from bending out laterally and thus having additional strain put on them. Further the springs are so arranged, that when running they are always stressed in one direction only. This drive has given excellent results in service. It is especially noteworthy that the wear at surfaces which are in frictional contact is extremely small. Breakage of the springs has

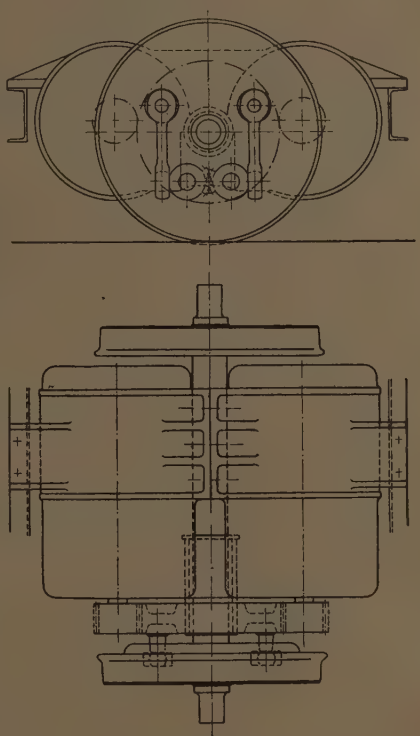


Fig. 13. — Buchli drive on the inside of the diving wheel.

(1) *Elektrische Bahnen*, 1927, p. 41, and 1928, p. 42.

TABLE 3.

Development of the Buchli drive with single and double motor for various classes of locomotives.

No.	Axle arrangement.	SERVICE.	Maximum speed km. per hour.	Number of motors.	ARRANGEMENT OF DRIVING GEAR.	Type of motor.	Weight in m. t. Electr. portion.	Weight in m. t. Mechan. portion.
1	1Do1	Express trains.	110	4		I	32	38
2	1Do1	Heavy passenger trains.	95	4			52	58
3	CC	Heavy goods trains.	65	4			52	60
4	1D	Light goods trains.	65	3			41	53
5	1C1	Light passenger trains.	75	2			30	50
6	1C	Shunting locomotives.	45	2			30	42
7	Fo	Heavy goods trains.	65	6		II	52	60
8	Do	Light passenger and goods trains.	75	4			36	40
9	$1A_0A_1$	Rail motor coaches.	75	2			21	39

hitherto not occurred and should not be expected. The oil consumption too is very small.

With the usual arrangement of gear using motors supported by the driving axle and suspended from the frame, important experiments were made by the Reichsbahn as far back as 1924. In this case it was only a question of locomotives having the low maximum speed of 45 km. (28 miles) per hour. The trials were very satisfactory. Great reliability was combined with low maintenance cost, ease in handling in the workshop, wherein simple and inexpensive arrangements were all that was required. In 1927 and 1928 very efficient goods engines were built on these lines, class 95, type 1 Co + Co 1 (see table 2), provided with axle-supported motors as described above. These locomotives have a maximum speed of 65 km. (40.4 miles) per hour so that they are capable in mountainous districts (Silesian mountain railways) of also hauling ordinary passenger trains at the speeds necessary to comply with the time-table. They have given excellent service ever since.

As the axle-supported motor had proved its suitability for passenger locomotives, the Reichsbahn decided to adopt this method of drive for higher speeds up to 110 km. (68.3 miles) per hour. First of all an express locomotive, 1 Bo + Bo 1, class E 18 (see table 2) was ordered.

As is seen by the arrangement of axles, the driving mechanism is carried on two bogies. The locomotive is employed on the section Halle-Leipzig-Magdeburg, on which numerous curves are encountered.

In order to test out on the same section an express locomotive with the same drive and of equal power but with a continuous frame, that is therefore with the axle arrangement 1 Do 1, a second locomotive with this modified arrangement was supplied. This design is likewise satisfactory although it does not take the curves so freely as the 1 Bo + Bo 1 locomotive.

5. — Measurement of vibrations in the driving mechanism.

The vibrations which occur in the driving gear of electric locomotives and especially the so-called jerking vibrations have been investigated by different experts (1).

Especially the notable work done by

(1) For example: A. C. Couvenhoven, *Ueber die Schüttelerscheinungen elektrischer Lokomotiven mit Kurbelantrieb*, Berlin, 1919, *VDI. publications.*

W. Kummer, *Die Beanspruchung der Lokomotiv-Parallel-Kurbelgetriebe ohne und mit Stichmassfehler und Lagerspiel. — Elektrotechnische Zeitschrift*, 1915, p. 311.

W. Kummer, *Die kritischen Drehzahlen der Parallel-Kurbelgetriebe elektrischer Lokomotiven.* Proceedings of the Schweizer Naturforschenden Gesellschaft, Berne, 1922.

E. Meissner, *Ueber Schüttelerscheinungen in Systemen mit periodisch veränderlicher Elastizität. Schweizerische Bauzeitung*, 1918, Vol. 72, p. 95.

Iwan Döry, *Die Schüttelerscheinungen elektrischer Lokomotiven mit Kurbelantrieb.* Braunschweig, 1923, Friedrich Vieweg & Sohn, Co.

Alfred Wichert, *Theorie der Schüttelschwingungen und Untersuchung der Schüttelerscheinungen von elektrischen Lokomotiven mit Parallelkurbelgetrieben.* Berlin, 1924, *VDI.* publications.

Kurt Vossius, *Schüttelerscheinungen an elektrischen Lokomotiven mit Schrägantrieben. Elektrische Bahnen*, 1927, p. 287. [Editorial note : See this article (Irregular vibratory movements of electric locomotives with inclined connecting rods) in the *Bulletin of the Railway Congress*, August 1928 number, p. 657].

A. Wichert has had a useful effect on the taking of measurements which have been carried out by individual locomotive builders in conjunction with the Reichsbahn.

While Wichert had to make use of a relatively imperfect apparatus, the vibrograph, later on instruments were developed, among others by the Bergman Electricitätswerke Co., which had the advantage over the vibrograph that the recording of the measurements was done electrically by means of the oscillograph.

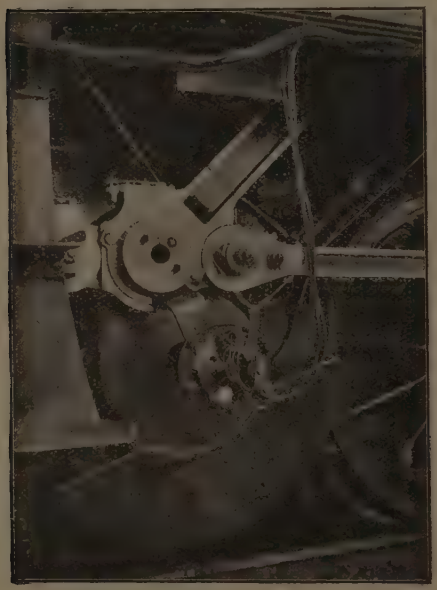


Fig. 14. — Fixing of the testing apparatus for measuring oscillations.

The actual apparatus for recording the impulses is quite small and can be readily applied to any part of the machine under investigation. It is connected with the oscillograph by means of fine conducting wires. By this method, moreover, several trains of vibrations can be taken up simultaneously, provided the oscillograph possesses the necessary number of measuring filaments. In contradistinction to the vibrograph the oscillograph records the higher frequencies satisfactorily.

The apparatus measures the difference between the rotatory movement of the axle or shaft under examination and a uniform movement. It consists essentially of a flat cylindrical disc, which is driven by the shaft under examination by means of the pressure of a light spring.

In consequence of its considerable « polar » moment of inertia, the disc rotates with practically uniform angular velocity.

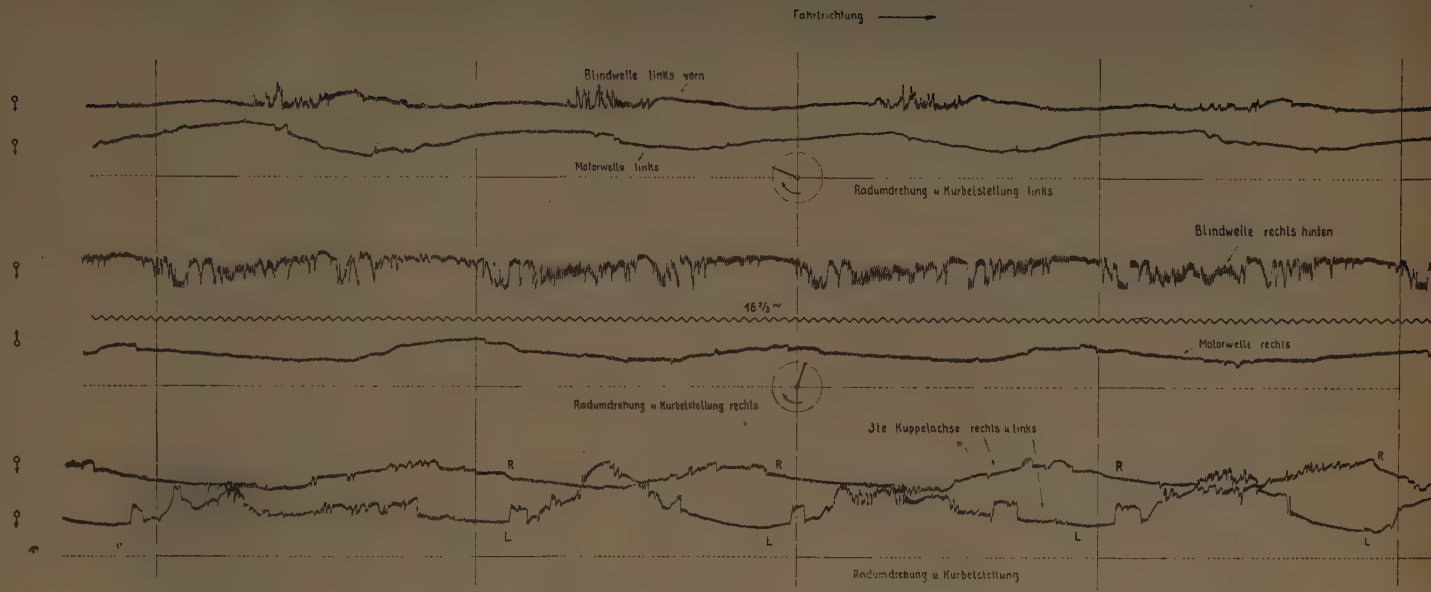
On the disc are two rolling curves which bear against a system of electrical resistances. The resistances are connected securely with the shaft under examination. Each turn of the disc in conjunction with the shaft causes the curves to roll on the resistances in one sense or the other, according to whether the rotatory velocity of the shaft is accelerated or retarded.

The resistance wires are arranged in the form of the Wheastone bridge. The bridge current is measured, and by means of suitable arrangement of shape and dimensions of the different parts and resistances, the bridge current is found to be proportional to the variation in angular velocity.

Figure 14 shows how the apparatus is applied to the lay shaft of a locomotive with coupling rods.

Figure 15 shows a small portion of the oscillograph diagram taken, among others, from a type E 75 locomotive (connecting rod drive).

The apparatus for these measurements was applied to the armature shaft, gear



Speed : about 7.2 km. (4.47 miles) per hour.

Angle of advance of crank.

Fig. 15. — Vibrations in different shafts of a locomotive of Class E 75.

Explanation of German terms: Blindwelle links vorn = Lay shaft, left, front. — Fahrrichtung = Direction of running. — 3te Kuppelachse rechts u. links = Third coupled axle, right and left. — Motorwelle links (rechts) = Motor shaft, left (right). — Radumdrehung und Kurbelstellung = Rotation of wheel and position of crank

wheel shaft, to the driving and coupled axles, and this was carried out moreover on both sides of the locomotive. The measurements were taken under varying conditions of speed and load, with different degrees of play in the bearings, with different spring and dashpot arrangements in the driving pinions and when running in either direction.

The curves obtained show very remarkable forms with many higher harmonics of different frequencies, peaks and zigzags and go to prove that the vibrations actually taking place in practical working are much more complicated than was expected in accordance with the theories hitherto held and the indications given by the vibrograph.

The results appear to indicate that most of the vibrations are produced by impulses, the frequency of which is equal to the speed of revolution of the driving gear.

The causes of the vibrations are therefore probably due to inaccuracies of gauges. Wichert has already drawn attention to this point.

6. — The single-phase series railway motor.

As already indicated in the first section the Reichsbahn employs a purely single phase series motor on its alternating current locomotives.

Not many years ago the principal objection to this type of motor was that it had a commutator with all its supposed drawbacks. One was especially afraid of sparking at the brushes, which according to the view of some experts would necessitate repairs at an earlier stage than for the other parts of the locomotive.

In the meantime, experience has taught us that the single phase series motor can be so designed and constructed that the commutator will remain in reliable condition at least as long as other parts of the locomotive. Naturally such a result could only be obtained after years of experience in the calculation and construction of the motors.

The difficulties met with in calculating the design especially in respect to the electro-magnetic system are increased, the more it is necessary to insist on a highly economic utilisation of the material. For reasons of pure economy the calculator and the designer have to endeavour to keep down the weight of the motor and also its price. This can only be achieved if all parts not only from a mechanical but also from the electromagnetic point of view, are utilised to the fullest extent, with the reservation that reliability and satisfactory operation are not thereby sacrified.

So long as the individual parts did not have to be utilised to the same extent as is required at the present day, the calculation of the electrical and magnetic values for the motor could be made on the assumption that the impressed electromotive force and the resulting currents developed in it were uniformly of a sinusoidal character. That is to say the calculation could be made by means of the ordinary vector diagram. This assumption led to results which gave satisfaction at that time.

Now the current curves are only sinusoidal when, with sinusoidal impressed electromotive force and with a correct design of main transformer, the resultant magnetic flux in the iron (1) is pro-

(1) The electric and magnetic units used are those proposed by the German committee for units and values. See also WECHMANN, *Der Elektromagnetismus*, Berlin, 1929, published by the *Verkehrswissenschaftlichen Lehrmittelgesellschaft, Ltd.* (Deutsche Reichsbahn).

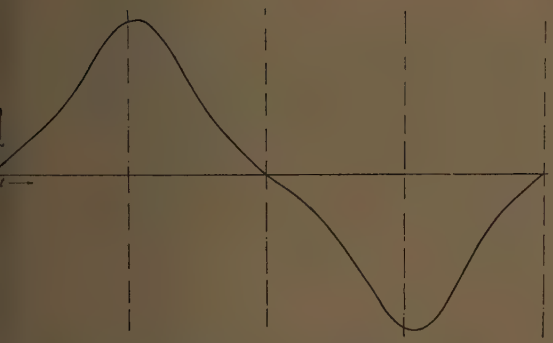


Fig. 16. — Oscillogram showing strength of current.

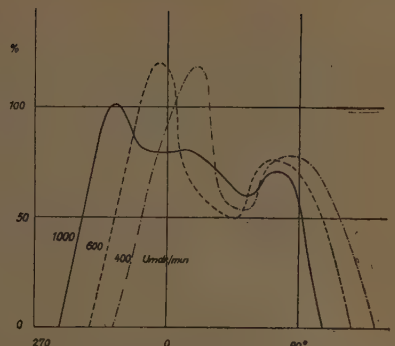


Fig. 17. — Calculated shape of curve of the stray voltages (Differential lines of the current curves).

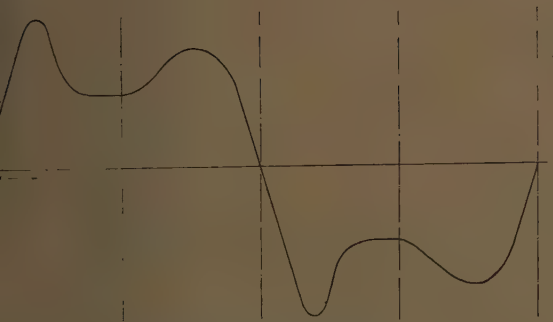


Fig. 18. — Oscillograph differential curve of the current. (Curve of stray voltage.)

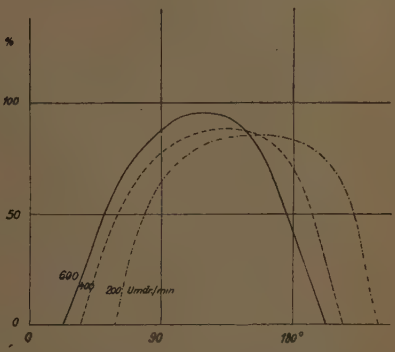


Fig. 19. — Magnetic flux according to the vector diagram.

Explanation of German terms: Umdr./min. = Revolutions per minute.

portional to the load $\frac{wJ}{l}$ as also to the intensity of the current (w = number of turns of windings, J, intensity of current, l = length of the path of magnetic field lines).

This proportionality however only holds for relatively low current intensity. Measurements taken with the oscillograph show that in the modern railway motors with a current corresponding to their rating on the hourly basis, the relation between magnetic flux and current intensity no longer obtains. Hence the former method of calculation would be inadequate for the design of the new high duty railway motor. If nevertheless the old method is adopted, the finished

motor will assuredly have quite different electrical characteristics than one would be led to expect according to the calculation, the question of commutation especially not lending itself to exact treatment.

A purely analytical treatment of the problem is extremely difficult if only for the reason that the so-called magnetic curves (flux density B as a function of the load $\frac{wJ}{l}$) cannot readily be expressed by an analytic function. Using a graphic method enables one to reach the result fairly simply and above all in a synoptical form. The method described below has been indicated by Dr. Töfflinger, Berlin (1).

The actual current curves (fig. 16) do not differ greatly from a sine curve. They are somewhat more pointed and reach their maximum slightly before the abscissa $\frac{\pi}{2}$. The increased loss in the copper is of no importance.

If the current curves are differentiated according to time, the curve form of the stray voltages is obtained. We then get by calculation, according to the sine curve that is based on the vector diagram, the curve shown in figure 17, whereas on the other hand the differential line of current as shown by the oscillograph has the shape indicated in figure 18. The variations between the two curves 17 and 18 are very considerable. It is to be noted that the stray voltage shown by the oscillograph is greater than indicated by the sine law calculation. The value obtained for the power factor is therefore less favourable than under the former method of calculation.

(1) Töfflinger, *Paper presented at the Technical High School*, Breslau.

The magnetic flux shown as a function of the time according to the old method of calculation is shown in figure 19; it is therefore approximately trapezoidal in shape. The differential line of the magnetic flux is the electromotive force of

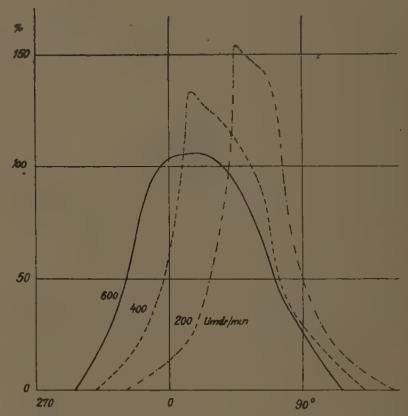
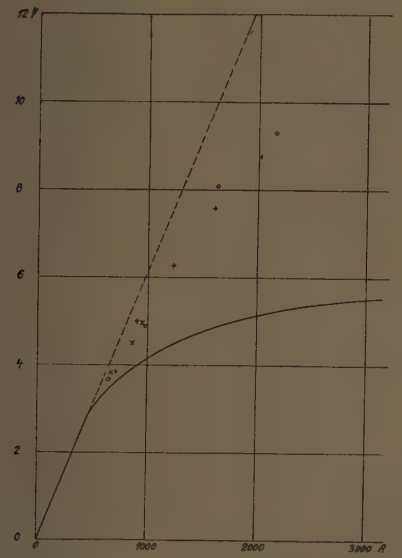


Fig. 20. — Calculated voltage of self induction at the exciting winding.

self induction of the exciter winding (field winding, figure 20). This curve is only approximately sinusoidal when the current is very small. When approaching saturation of the iron the curve shows a sharp peak. The electromotive force of self-induction which results is materially higher than that obtained by calculation with the vector diagram. The quality of the commutation of the motor depends on the voltage which is induced in the armature windings by the alteration in the value of the magnetic flux. This is likewise shown by a curve of the form indicated in figure 20. Now sparking at the brushes does not depend on the effective or virtual value but on the *maximum* value of the difference of potential arising between adjacent commu-

tator segments. Here, as will be seen from figure 21, very considerable differences are shown between the two methods of calculation. The curve shows that with increasing current, that is with



Calculated assuming sinusoidal curves o, +, × arrived at graphically for 300 v., 200 v. and 100 v.

Fig. 21. — Maximum values of voltages between adjacent commutator segments.

increasing saturation of the iron, there is a materially greater increase of sparking than is indicated according to the vector diagram. This fact is of the highest importance in considering the dimensions of the latest types of railway motors.

The question of safety against flashing over at the commutator, depends on the voltage between adjacent commutator segments not lying in the zone of commutation. The curve of these voltages obtained by the graphic method is shown in figure 22. This curve likewise tends to a sharp peak with increasing saturation of the iron, and here again it should be noted that it is the maximum value of the voltage which governs the conditions for flashing over. The old method of calculation does not show these peaks in the curves.

The new method of calculation referred to shows how to calculate the motor in such a way as to obtain satis-

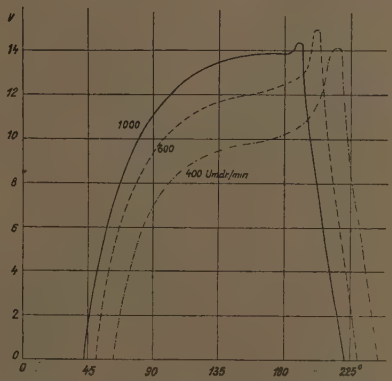


Fig. 22. — Difference of potentiel between adjacent commutator segments, not located in the commutation zone.

factory commutation while taking full advantage of the electro-magnetic properties of the motor.

The means for arriving at this result are among others :

1. Increase of the air gap compared to earlier designs. This results in a magnetic flux curve which is more nearly sinusoidal and hence all the remaining alternating current values have a similar shape following a similar law.

2. A reduction in the value $\frac{wJ}{l}$ as compared with earlier practice, either by reducing the number of turns of the exciter winding or by connecting an inductive resistance in parallel with this winding.

3. Connecting an ohmic resistance in parallel with the exciter winding. This decreases the susceptibility of the stator iron. The more dangerous peaks in the voltages induced in the armature windings are damped down.

7. — Air break main switch.

The construction of the oil switches hitherto supplied as main switches for the locomotives has been greatly perfected to meet the increased requirements due to larger power stations, so that the oil switches supplied to present-day locomotives of the Reichsbahn (1) are equal to any demands that may arise under service conditions. Nevertheless cases may arise when these oil switches are unsatisfactory. For instance, there may be feeding points on the line which are very close to power stations of great capacity. At such points the locomotives are subject to very heavy short circuit loads. On the other hand at other points of the network long feeders together with parts of the trolley line itself form protective reactances in series with the oil switches.

It would not be justifiable to fit the locomotives with oil switches large enough to meet the most unfavourable conditions; on account of the necessary freedom of action of the locomotives they would all have to be supplied with the large type of switch. The difficulty has therefore been dealt with by arranging that any short circuit, which may occur in the locomotive in places which are on the supply side of the main transformer, should be controlled for breaking purposes by the oil switches installed at the substations. This is easily arranged by giving the locomotive oil switch a suitable time lag.

As an overload on the oil switch might result in setting fire to the oil or in causing an explosion of oil gases, it is desirable to elimitate the oil from the switch. That is to say the same tendency obtains which governs the replacement of the oil-cooled transformer by an air-cooled transformer. Such oil-less switches are, it is true, not yet in service on the Reichsbahn. On the other hand an experimental switch has been made which appears suitable for trying out in service at an early date. This switch (fig. 23) works with a multiple break and quick-acting compressed air operation and in addition has a magnetic blow-out. The switch has been severely tested on the bench and has fulfilled requirements, namely the opening and closing of the switch on short circuits.

Another design of oil-less or air break locomotive switch is shown in figure 24. This design has not yet been carried out but a trial is in view at an early date. The arc is broken by a high speed current of compressed air. By suitable symmetrical design of the contacts with reference to the air jet the arc cannot be displaced in any direction while it is being blown out. The movable portion of the contact is drawn into a region of very high air pressure, where a reinstatement of the arc is prevented by the increased break-down resistance.

When the overload relay operates, a

(1) *Elektrische Bahnen*, 1925, p. 332.

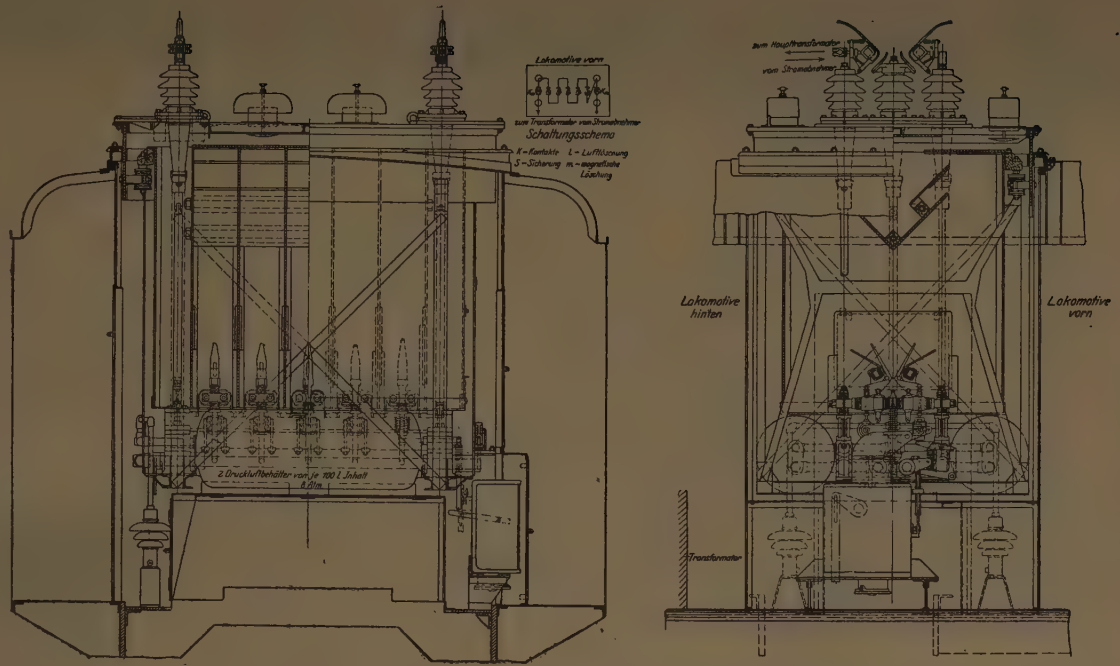


Fig. 23. — Locomotive air break switch. Built 1928. Length (measured in the running direction): 1 500 mm. (4 ft. 11 in.); Width: 2 000 mm. (6 ft. 6 3/4 in.); Total height 3 000 mm. (9 ft. 10 1/8 in.).

Explanation of German terms: Lokomotive hinten = Facing rear of locomotive. — Lokomotive vorn = Facing front of locomotive. — Schaltungschema = Circuit diagram. — Zum Haupttransformator = To main transformer. — Zum Transformator vom Stromabnehmer = To the transformer, from the current collector. — 2 Druckluftbehälter von je 200 l. Inhalt = 2 air reservoirs, each of 44 Br. gallons capacity.

K = Contacts.
S = Fuse.
L = Pneumatic blow out
m = Magnetic blow-out.

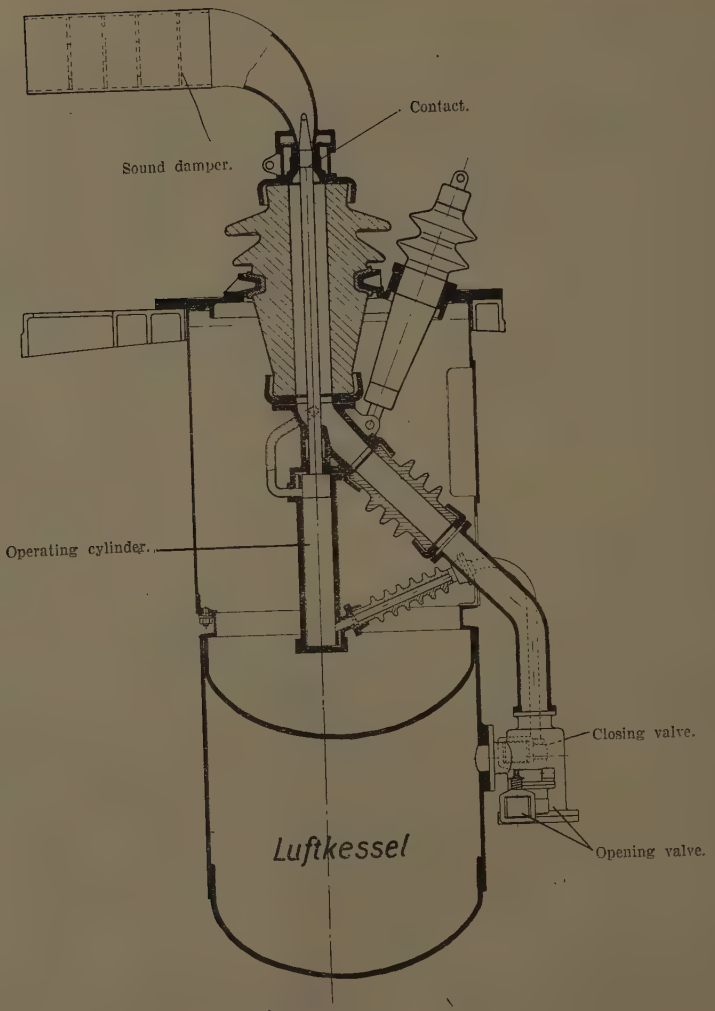


Fig. 24. — Arrangement of air break switch (diagram).

Explanation of German terms: Luftkessel = Air reservoir.

compressed air valve opens the switch and at the same time admits compressed air from a reservoir, which air is driven in the direction of the arc. The locomotive air pump is used for recharging the reservoir.

8. — Control with fine regulation.

The types of contactor and sliding contact controllers which are installed in a large number of electrical locomotives of the Reichsbahn are well known from descriptions in technical books and magazines (1).

In addition there is in use on goods locomotives Class E 75, a type of controller which has been given the name of close or *fine regulation control*. Its method of operation is distinguished from other controllers, in that the switching is entirely sparkless and that at starting and on increasing load, the tractive effort is increased gradually and not by jumps. This characteristic enables the driver to control the tractive effort in such a way that it is always close to the limit when slipping of the driving wheels would take place.

The close regulation control for the Reichsbahn locomotives is designed for hand operation. Hand operation on account of its simplicity offers advantages as against motor operation on account of simplicity of maintenance and security of operation. Naturally motor operation can be applied, so long as suitable means are adopted to break the motor current quickly when it is switched off.

The hand operated control (see fig. 25) comprises a drum controller, an intermediate transformer, the actual « fine regulation apparatus » and the necessary operating shafts, etc.

The stepped controller consists of single contactors which are operated through contacts on a revolving drum. The intermediate transformer takes the place of the usual arrangement for sub-dividing the current when contactor controls are used. In addition to the main winding, it has an exciter winding which only carries current during the movement from one contact to the next. The actual fine regulation arrangement consists of a face plate switch with brushes 180° apart. The contact segments of this switch are connected through resistances with the winding of a voltage divider.

Each of the thirteen contact stages is protected by two breakers with the exception of stage 1 which, in view of the relatively small current for starting, is only provided with one. Figure 26 shows the circuit conditions when working on stage 2 of the controller. It will be seen that breakers 1 and 2 are closed, and the secondary winding 16 (main winding of the intermediate transformer) is under load, while the primary winding 17 (exciter winding) only carries the very small magnetising current. After breaker number 1 has opened the conditions are as shown in figure 27. While the breaker has been opened the brushes of the fine regulator have been moved round to an angle α. The voltage e_1 at the intermediate transformer and the voltage E at the driving motor have remained unchanged. The load EJ taken up by the motors has not been changed by the opening of the switch. In other words the load has been neither increased nor decreased. The breaker 1 therefore opens sparklessly. It is true that it has to break a current $\frac{J}{2}$ but apart from inductive or ohmic fall of potential in the transformer windings, the difference of potential between the contacts of the breaker after opening is equal to zero. Hence the switch duty is equal to zero. There remains, therefore, to provide some means, by which the current $\frac{J}{2}$ may be interrupted,

(1) *Elektrische Bahnen*, 1927, pp. 83 and 235; 1929, supplement, p. 44.

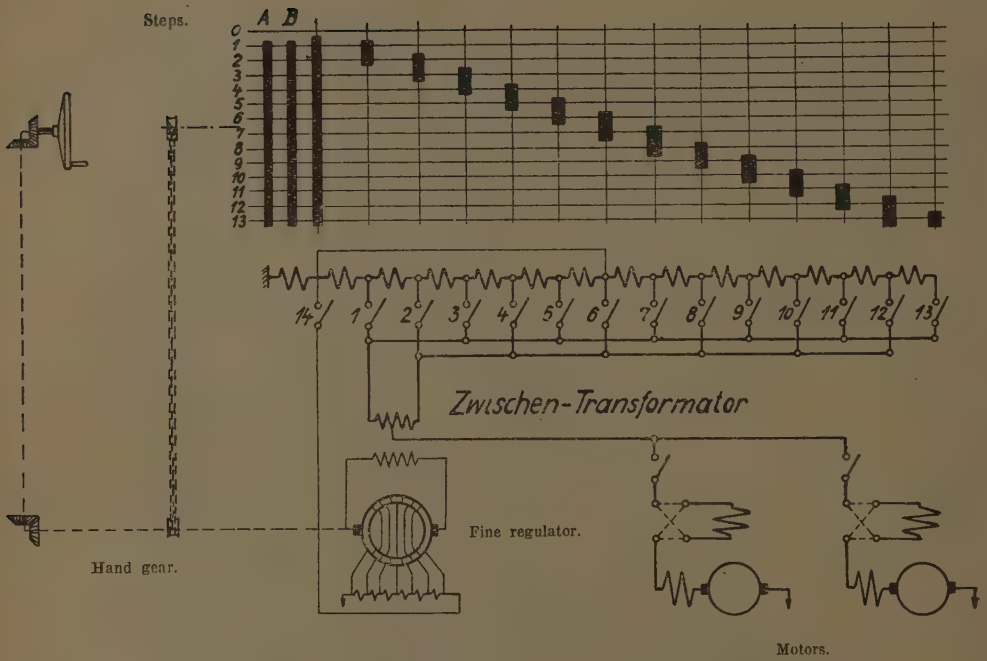


Fig. 25. — Diagram of fine regulation control arrangement.
Explanation of German terms: Zwischen-Transformator = Intermediate transformer.

but the potential existing between the contacts of the breaker 1 is to be transferred to breaker number 2.

The actual voltage regulation commences after switch 1 has been opened, namely by the movement of the face plate regulator brushes through a given angle.

In this case the voltage e_2 between the brushes of the regulator is gradually reduced to zero. Consequently the voltage e_1 gradually diminishes and finally drops to zero. The voltage at the motor has then increased to $E + \frac{e}{2} = E_1$ (fig. 28). If the brushes on the regulator are now turned further round, e_2 and hence e_1 commence to rise again, but in an opposite sense. If in the first instance the excess current taken from the transformer at the number 2 tapping was returned, by transformation, through the intermediate transformer and fine regulator, to the low pressure winding of the main transformer, the process is now reversed and the deficiency in current at the same point is made good by transformation and supplied to the main transformer (fig. 29). If the brushes have reached the position indicated in figure 29, the regulation process for one step on the controller is concluded. By this time e_1 has become both as regards value and sense equal to the

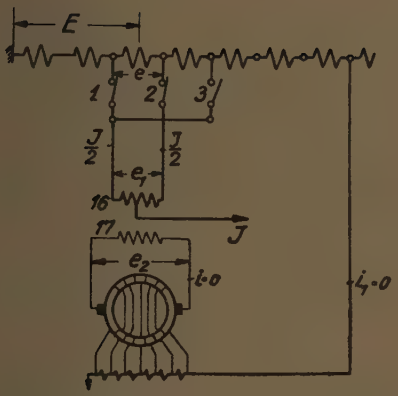


Fig. 26. — Fine regulation control on step No. 2.

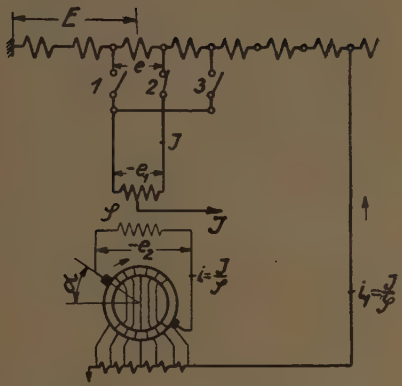


Fig. 27. — Fine regulation control during movement between steps 2 and 3.

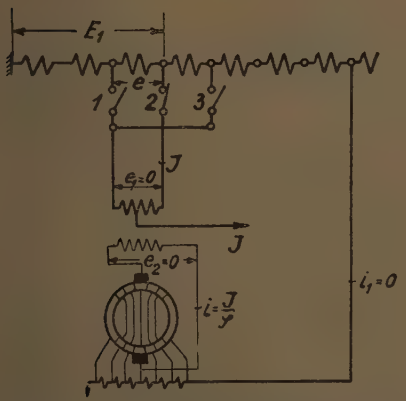


Fig. 28. — Fine regulation control. Voltage regulation between steps 2 and 3 half completed.

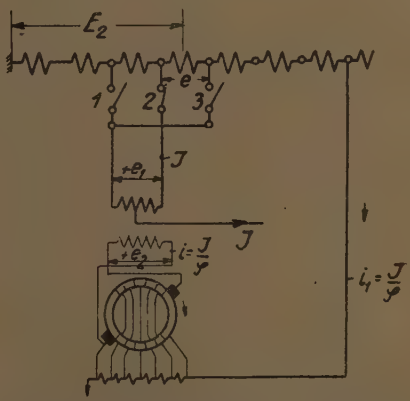


Fig. 29. — Fine regulation control. End of voltage regulation between steps 2 and 3. — Contact 3 may be closed.

intermediate potential e, so that the breaker 3 may now be closed. This closing, as in the case of opening, takes place practically without sparking. The changes in voltage which take place at the terminals of the motor and at the fine regulator during the transition from stage 2 to stage 3 is shown diagramatically in figure 30.

The general arrangement of the fine regulation control is shown semi-diagramatically in figure 31. The contacts

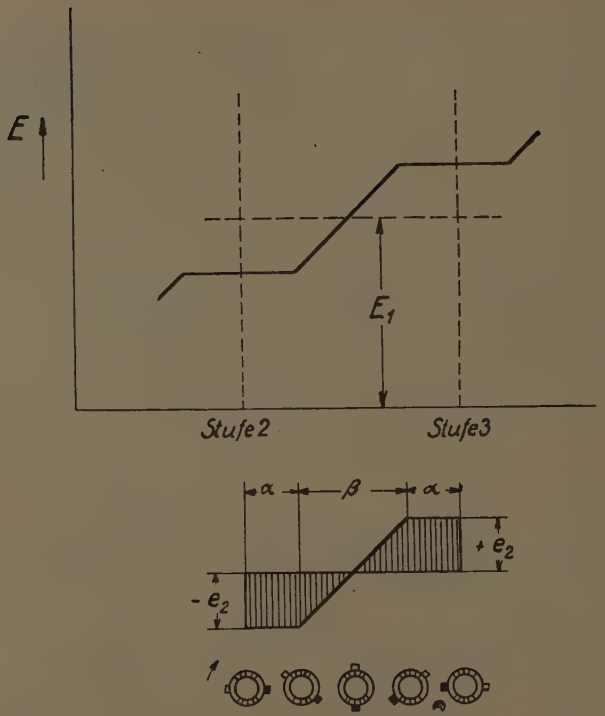


Fig. 30. — Voltage variation at the motor terminals when moving from control step 2 to 3.

on the controller drum operate bell crank levers whose movement is transmitted to the movable part of the circuit breaker by means of an insulator 18. The drum shaft and fine regulator shaft are coupled together by a Maltese cross device. This has the effect that the drum shaft is practically at a standstill during the actual regulating process. This latter only moves when the regulator brushes are moving over the wide segments of the face plate.

As already stated, the engine driver is able to adjust the tractive effort of his locomotive to the frictional conditions existing between the driving wheel and the rail, by slow operation of the hand wheel. With a little practice it is found that he can maintain the current in the motor at a constant figure at starting. A curve showing the starting current conditions and acceleration for a 600-ton express train is shown in figure 32. The current in the motor, after it has reached the figure necessary for starting, remains steady until the output limit of the motor has been reached (see also oscillograms of figure 32). If the driver

moves his control more quickly than he should do for steady current conditions, or if he holds his control stationary for a short time on one of the steps of the controller the current varies only slightly from the straight line. In no case does the tractive effort vary with sudden increases even if the hand wheel is turned very quickly. For this reason the average starting current can be fixed at a higher figure when employing the fine regulation control arrangement than with the ordinary relay control, provided in both cases the same R. M. S. value of the current in the driving motors is admitted

From this it follows, that with the fine regulation control it is possible to obtain a higher acceleration at starting than with the ordinary control by steps.

9. — **Interlocking of control and brakes.**

It may happen that occasionally the driver may switch current on to the motors before all the brakes are completely off. It is therefore of importance from the point of view of preventing damage to the motors and wear on the tyres and thus saving in maintenance costs, if an automatic arrangement is provided which prevents current from flowing into the motors when brakes are on. With the ordinary electro-magnetic contactor control it is sufficient if the controller current is cut off. The Reichsbahn has introduced such cut-outs experimentally on several locomotives and rail motor coaches.

Information has been published in the Technical Press regarding the design and behaviour of such a cut-out (1).

According to the latest design the breaker switch is operated by the piston of a small pneumatic cylinder which is connected to the brake pipe. The cut-out switch closes the circuit on the small relay, which operates so as to keep open the controller current so long as there is pressure on the piston of the brake cylinder. The controller current circuit is only closed by the above mentioned relay when the pressure in the brake cylinder and thus also in the small cylinder has fallen to a very small value (about 11 lb. per sq. inch).

10. — **Dead man's handle and safety gear.**

One of the advantages of the electric locomotive over steam locomotives and other engines carrying their own supply of power consists in the fact that only one man is necessary to operate it. A conscientious management must however reckon with the fact that an accident may happen to the driver which would render him incapable of carrying out his work. In such a case the locomotive, if another man is not immediately to hand, would be left uncontrolled which would probably result in a more or less serious accident. To meet this difficulty some railways have fitted the control which the driver has to operate, with additional apparatus which in case of failure of the driver, automatically bring the locomotive to a stop by first of all cutting the current off the driving motors and then applying the brakes. Such arrangements are provided both with clockwork operating gear which can be set as required and also with a gear operated from the locomotive axle; that is to say the safety gear does not operate at the moment when the driver ceases to control but only in the one case after a definite adjustable time period or after the locomotive has run over a definite adjustable distance.

(1) *Elektrische Bahnen*, 1929, pp. 56 and 335.

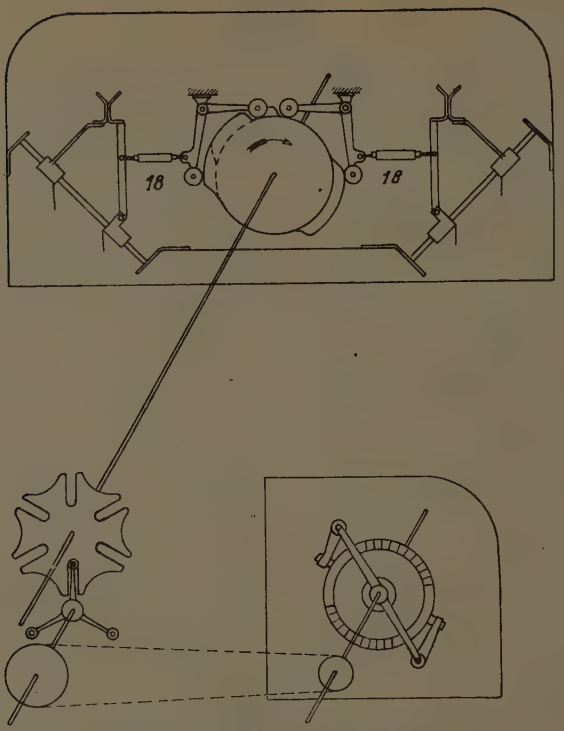


Fig. 31. — Principles of construction of the fine regulation control.

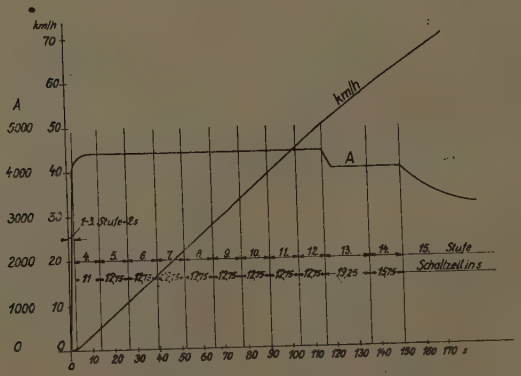
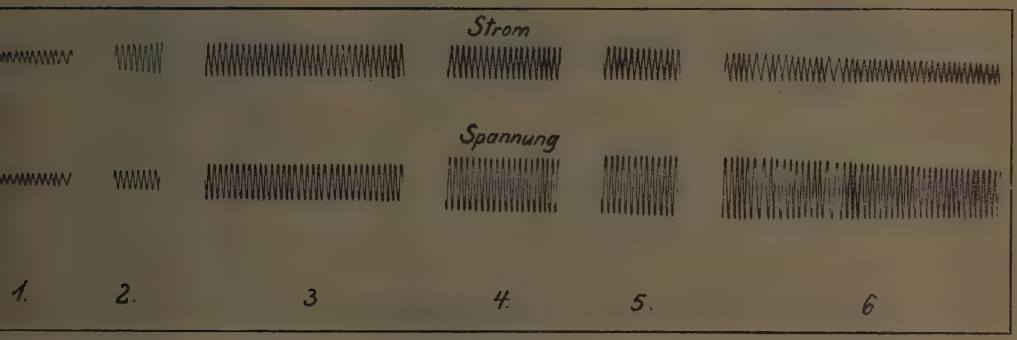


Fig. 32. — Voltage variation when starting a train with fine regulation control.



itching over step 1 tep 2. | 2. Switching over from step 4 to step 5. | 3. Switching over from step 6 to step 7. | 4. Running on step 9. | 5. Running on step 10. (current decreases owing to increasing speed). | 6. Switching off current.

Fig. 32*a*. — Oscillogram of current intensity and voltage with fine regulation control.

The method of operation of these safety gears may be assumed to be known (1) especially as some railways, for instance the Swiss Federal Railways, have had them in use for some years.

The Reichsbahn likewise has provided its electric locomotives, beginning in the year 1927, with such a safety device. But it has not yet come to a decision regarding the final form of the apparatus. At the moment several designs are in use. The following particulars are restricted to the alterations and improvements resulting from the employment of the apparatus for engines of different designs and brought about by the very strict requirements of the Reichsbahn as regards reliability.

The arrangement as has already been stated must, in addition to putting on the brakes, likewise switch out the motors so that the braking is not effected while the motors are loaded. With the relay contactor controls of locomotives of different designs, the current may rise as high as 20 amperes. To deal with a current of this intensity it is necessary that the electrical contacts in the apparatus must operate with a pressure of several kilogrammes. As a pressure of this magnitude could not be obtained directly by the magnet itself, the control current breaker was designed to operate by compressed air in one particular type of apparatus. The pneumatic cylinder of this switch is connected with the space immediately above the brake valve. Consequently, when the brake valve on the safety gear is operated, the compressed air switch is operated simultaneously, and the cylinder space is equally exhausted through the brake valve.

The compressed air switch operates likewise if the pressure in the brake pipe is diminished from another direction, that is, for example. in case of operation

(1) Bibliography : Brown-Boveri, *Mitteilungen*, 1927, p. 137; 1928, p. 174; 1929, p. 268. *Elektrische Bahnen*, 1926, p. 407; 1928, p. 89; *Supplement*, 1929, p. 62; A. E. G., *Mitteilungen*, 1928, vol. 1.

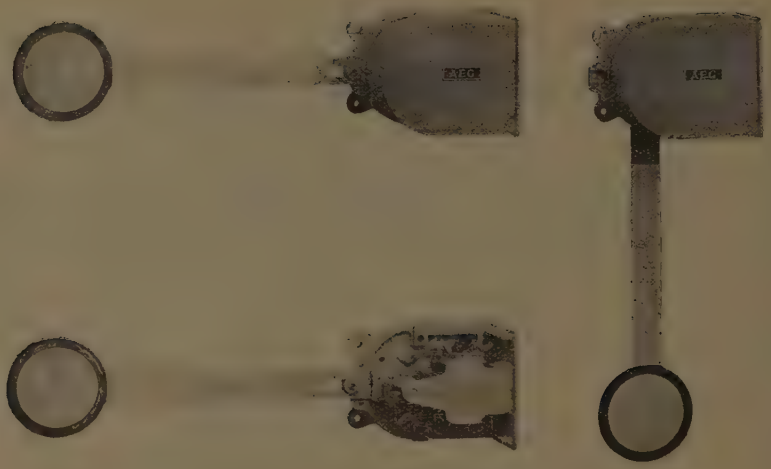


Fig. 33. — Emergencyshort -circuiting device for cutting out the safety gear.

Explanation

t_1 = Time up to the start of braking.
t_2 = Time up to the stopping of the train.
s = Distance run up to the stopping of the train

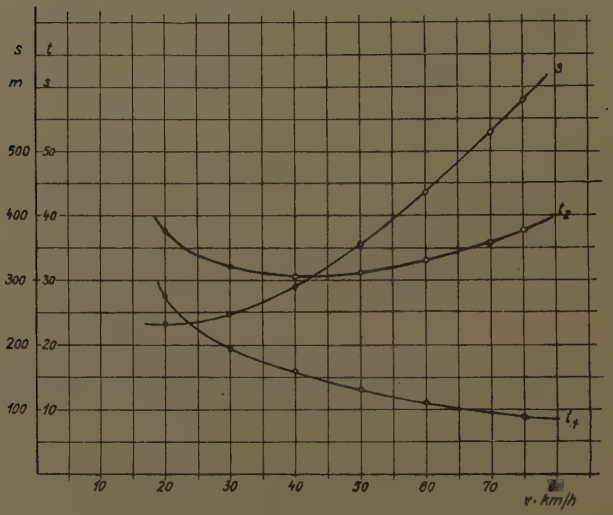


Fig. 34. — Braking test with safety gear operating.
Locomotive class E 32, weight of train 226 tons.

of the emergency brake. Thus in the event of unexpected application of the brakes the motors, should they be switched on at the time, are not overloaded. In the same way the arrangement prevents the braking distance of the train from being increased by the motors being connected up to the current supply.

Although in designing this arrangement great weight was given to the necessity of employing apparatus of robust design, it appeared advisable, in case of trouble, to give the driver means to put the apparatus out of action and to carry on with a second man in the driver's cabin. For this purpose an emergency short circuiting switch is fitted in every cabin. In case of trouble the driver has to move a lever the handle of which normally stands at the indication « one man », to the position indicating « no man ». Thereupon the driver depresses the lever of the emergency short circuiting switch downwards in *both* driver's cabins. This lever carries at its end a signal disc (fig. 33). When the short circuiting switch has been operated the signal disc which is very noticeable owing to its size and colour, appears at one of the windows of the driver's cabin and thus indicates that the locomotive is being run without safety gear.

In order to obtain definite information regarding the braking distances and braking periods which are obtained with the safety apparatus, the Reichsbahn arranged for brake tests in conjunction with the firms supplying the locomotives. The result of such a test is shown in figure 34.

The time lag was set for a distance of 200 m. (656 feet) to be run from the point at which the safety switch is allowed to come into action to the point when the brake valve commences to function. The curve s which shows the distance run during the initial period in relation to the speed of the train, approaches, at its lowest point, the 200-metre set distance.

In consequence of the increase of the braking distance as seen on curve s and the decrease of the time value t_1 which stands for the period from starting of the apparatus till the brakes commence to operate, the total time t_2 which covers the period up to the moment when the train comes to a stand, varies relatively slightly for the different speeds. The minimum value of t_2 is obtained at a medium speed of 45 km. (28 miles) per hour.

11. — Electric braking.

Electric braking and the ability to return power to the line are undisputed advantages possessed by the electric locomotive over the steam engine. The recovery of energy, that is, regenerative braking, is no more complicated with a single phase alternating current system than it is with continuous current supply. Practical circuits have been devised by means of which the speed of the train on a falling gradient can be regulated simply and exactly. The technical and economical advantage of regenerative braking on long and steep gradients is well known. Gradients possessing these characteristics to a sufficient degree are however not in existence on those routes of the Reichsbahn which are worked by electric power.

Hence up to date it did not seem to be necessary nor particularly advantageous to develop the construction of locomotives suitable for regenerative braking.

On the other hand the Reichsbahn has a resistance brake on its alternating current locomotives of the series E 91 and experimentally on those of the series E 95

(see table 2). The necessary brake equipment for this could be accommodated on the engines without any objectionable increase in weight. When the braking circuit is closed the motors are excited by alternating current from the trolley wire; the armatures work on resistances. Naturally this type of braking is limited to comparatively small retarding forces. On a gradient of 1 in 50, the weight of the locomotive alone can be braked, on lesser falling gradients a portion of the weight of the train which is being hauled can also be braked.

CURRENT PRACTICE.

[621.138 2]

Coaling of locomotive engines, London and North Eastern Railway Company.

Figs. 1 to 4, pp. 1348 to 1350.

With a view to speeding up coaling operations and in order to reduce the cost of handling the coal, the London and North Eastern Railway Company has recently put into operation an electrically operated coaling plant of a new design at the engine sheds, Kipps, situated between Glasgow and Edinburgh.

The plant was designed and constructed by Messrs. Henry Lees and Co. Ltd., Glasgow, to the requirements of Mr. H. N. Gresley, C. B. E., Chief Mechanical Engineer, London and North Eastern Railway Company.

The object of this plant is to enable enginemen after bringing their engines to the coaling chutes to quickly obtain the necessary amount of coal by simply setting in motion an electric motor, and at the same time, have each engine number automatically registered on a tape, together with the quantity of coal taken by the engine.

This result has been attained in the following manner :

A ferro-concrete structure was erected at a convenient position in the engine shed yard, forming an overhead storage hopper with a capacity of 200 tons. This hopper is divided into two compartments one containing 125 tons of second grade coal and the other 75 tons of first grade coal. Each compartment has an outlet at the bottom, allowing coal to deliver on to an endless steel belt conveyor or « cubi-meter ». Each « cubi-meter » is driven by a 4-H.P. motor, and when this motor is started, coal is carried forward from the hopper outlet at a fixed speed and depth, and fed on to a two-way flap fitted under the outlet from which it falls on to the tender of the engine standing underneath.

This two-way flap diverts the flow of coal up or down line and facilitates the coaling of tank engines. This arrangement also allows the coal to heap up centrally on the tender and avoids spillage. In addition, when in the horizontal position it acts as a safety device, as it prevents coal falling on to passing engines.

An electrically operated recorder is geared to each « cubi-meter » and as coal is passing to the engine tender, the amount in hundredweights is visibly shown on the recorder dial. The registering tape is incorporated in the recorder.

The « cubic meters » which are set to deliver coal to the engines at the rate of 1 1/2 tons per minute, are operated in the following manner :

One of the enginemen steps from the footplate of his engine on to a small platform, on which the key rack is carried. He selects the key containing the number corresponding to the engine number. This key is inserted in the recorder when the number is automati-

Fig. 1.

cally registered on the tape and with a half turn of the key, an electric switch is depressed, energising the « cubi-meter » motor, and driving the conveyor belt carrying the coal forward. The key may now be withdrawn, and when sufficient coal has been taken, the conveyor belt is stopped by pressing a

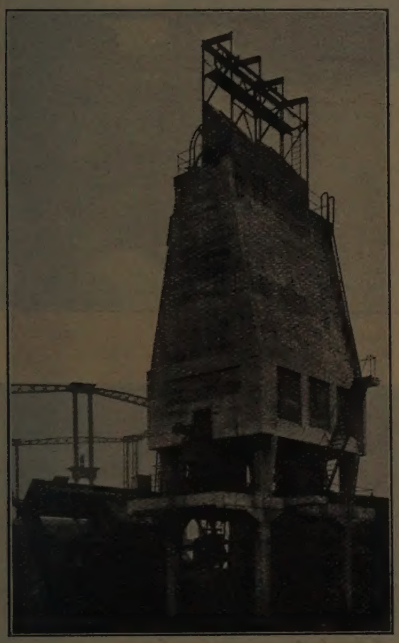


Fig. 2.

stop switch fitted to the recorder At this instant, the quantity of coal taken is automatically registered on the tape opposite the engine number.

An accurate record is therefore available, of the coal taken by every engine using the plant.

The amount of coal flowing through the « cubi-meter » can be adjusted to agree with the figures shown on the recorder by the raising or lowering of a gate which regulates the depth of coal passing on the endless steel belt.

The coaling of the overhead storage hopper is carried out with the following equipment :

A wagon tippler of the side-throw counterbalanced type, capable of lifting wagons of 8 to 20 tons capacity over a receiving hopper 6 ft. 6 in. above rail level. The counterbalance weights perform the dual purpose of economising power during lifting. and sustaining the wagon over the hopper when in the final tipping position.

The coal is taken from the receiving hopper through two outlets, each housing a chain feeder. Each feeder is driven by a small motor of 2 H. P. and operates in conjunction with a skip-hoist consisting of two skips, each of 1 ton capacity, which are hoisted on guide runways to the top of the storage hopper and tipped into the receiving chute. The skip-hoist motor can be operated independent of the feed motors, but during normal working the skip-hoist and feeder motors are electrically interlocked for automatic operation.

A two-way flap to divert the coal into the compartment which it is desired to fill, is fitted to the bottom of the receiving chute on the top of the storage hopper. This flap is operated through a hand winch fixed to the recorder platform.

To coal the storage hopper, the push-button switch controlling the feeder motors, is pressed to the « on » position. Whichever skip is in the down position, will be filled to a pre-determined weight. This weight is fixed by an adjustable weightometer operated by the tension on the hoisting ropes. This weightometer, in turn, operates a relay switch controlling the skip-hoist and feeder motors.

When the feeder is automatically stop-

Fig. 3.

Fig. 4.

ped, the loaded skip immediately ascends and the empty skip descends to the filling position, and is automatically filled. This cycle of operations continues so long as there is sufficient coal in either skip to operate the weighto-meter or until the stop switch is pressed by the attendant.

An attendant is only required at the plant during the filling of the storage hopper, which takes approximately three hours.